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ART. I.—*Contributions to Meteorology: being results derived from an examination of the Observations of the United States Signal Service and from other sources;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Sixteenth paper. With a map.

[Read before the National Academy of Sciences, Philadelphia, Nov. 15, 1881.]

Mean annual rain-fall for different countries of the globe.

WHEN we attempt to analyze the phenomena of storms, we immediately find evidence of the operation of general causes which are not peculiar to any particular storm. We see this truth illustrated by the tracks which storms pursue, and by the unequal amounts of rain which are precipitated at different places. In the case of any particular storm it is difficult to decide how much influence is to be ascribed to general causes, and how much to special causes. The influence of general causes is sometimes best shown by the averages derived from a large number of cases, by which means the peculiarities of particular storms are mostly eliminated. With this view I have undertaken to study the average annual distribution of rain for the entire globe. A comparison of the mean annual rain-fall for different localities shows unequivocally the influence of general causes quite distinct from the peculiarities of particular storms. These general causes must operate upon each storm, and a distinct understanding of their nature must assist

us in explaining the phenomena of particular storms. For many years I have been desirous of making a comparison of this kind, but have been prevented by the deficiency of observations of rain-fall for large portions of the earth's surface. Having at length succeeded in collecting observations from a pretty large number of stations, I have undertaken to compare them and to represent the results upon a map by lines of equal rain-fall. I am well aware that for certain portions of the globe (especially for the southern hemisphere), the observations are too few to enable us to draw the lines of equal rain-fall with confidence; yet I trust this imperfect effort may be useful in assisting us to understand the causes which influence the amount of rain-fall at particular localities.

The following table presents a portion of the results which I have collected, and the observations are divided into groups depending upon the amount of the mean annual rain-fall. The first group contains all the cases I have found in which the mean annual rain-fall exceeds 200 English inches; the second group contains cases in which the annual rain-fall is less than 200 inches, but greater than 150 inches; the third group contains cases of rain-fall from 150 to 100 inches; the fourth from 100 to 75 inches, the fifth from 75 to 50 inches, the sixth from 50 to 25 inches, the seventh from 25 to 10 inches, and the eighth group contains cases in which the mean annual rain-fall is less than 10 inches. This table shows all the stations I have found where the annual rain-fall is specially remarkable either for its great or for its small amount, and for those regions of the globe where only a few scattering observations have been found, all known cases have been inserted in the table; but for those countries where the stations of observation are numerous, only a small portion of the whole number have been retained. If I had inserted in my table the results for all known stations, the list would have filled a large volume. The number of stations in the United States at which the rain-fall has been measured is over 1200; the total number of rain-gauges now regularly observed in Great Britain is about 2200; and there are numerous stations of observation in every country of Europe. In British India the rain-fall has been measured at more than 350 stations, at many of which the observations have been continued for more than twenty years; in the islands of the Asiatic Archipelago, belonging to Holland, the rain-fall is measured at 124 stations; and there are numerous stations of observation in Australia, Africa and elsewhere. All available observations have been consulted in drawing the lines of equal rain-fall upon the accompanying map, but only a small part of them are contained in the following table.

Mean Annual Rain-fall for various stations.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
1	Cherapunji, Assam	4125	25° 14′ N.	91 40 E.	16–22	492·45	India, 1878, p. 116
2	Buxa Fort, Bengal	....	26 47 N.	89 36 E.	9–10	217·58	India, 1878, p. 115
3	Sandoway, Burmah	0	18 10 N.	94 5 E.	16–18	213·54	India, 1878, p. 120
4	Mahableshwar, Bombay	4540	17 56 N.	73 38 E.	22–24	253·24	India, 1878, p. 117
5	Baura, Bombay	....	16 29 N.	74 0 E.	5– 7	260·65	India, 1878, p. 117
6	Matheran, Bombay	....	19 0 N.	73 12 E.	10–13	255·41	India, 1878, p. 118
7	Uttray Mullay	4500	8 39 N.	77 0 E.	2	267·21	Phil. Trans., 1850, p. 358
8	Buitenzorg, Java	869	6 36 S.	106 47 E.	1	220·72	Bergsma, 1879, p. 217
9	Pelantoengan, Java	2274	7 6 S.	109 59 E.	1	235·64	Bergsma, 1879, p. 219
10	Oenarang, Java	1027	7 8 S.	110 23 E.	1	205·04	Bergsma, 1879, p. 219
11	Padang Pandjang, Sum.	2559	0 30 S.	100 30 E.	1	282·33	Bergsma, 1879, p. 223
12	Amboina, Island	....	3 42 S.	128 10 E.	1	226·06	Bergsma, 1879, p. 225
13	Matouba, Guadeloupe	4000	16 5 N.	61 50 W.	1	292·33	Comp. Rend., v. 7, p. 743
14	San Luis de Maranhao	....	2 31 S.	44 18 W.	1	280·00	Humb's Tr., v. 5, p. 270
15	Sylhet, Assam	....	24 53 N.	91 47 E.	22–26	154·28	India, 1878, p. 116
16	Akyab, Burmah	20	20 8 N.	92 52 E.	21–22	196·63	India, 1878, p. 120
17	Kyouk Phyoo	0	19 24 N.	93 34 E.	13	170·30	India, 1878, p. 120
18	Moulmein, Burmah	87	16 29 N.	97 40 E.	29	189·39	India, 1878, p. 120
19	Tavoy, Burmah	0	14 7 N.	98 18 E.	21–22	193·83	India, 1878, p 121
20	Mergui, Burmah	0	12 33 N.	98 48 E.	14–15	150·55	India, 1878, p. 121
21	Rungbee	5000	27 N.	88 E.	4	170·5	Haughton, Ph. Geog.
22	Lanauli, Bombay	....	18 48 N.	73 26 E.	5	162·93	India, 1878, p. 117
23	Ratnapura, Ceylon	....	6 35 N.	80 22 E.	9	151·73	India, 1878, p. 120
24	Attaghery	2200	8 N.	77 E.	1	170	Phil. Trans., 1850, p. 362
25	Augusta Peak	6200	8 N.	77 E.	1	194	Phil. Trans., 1850, p. 362
26	Sindola, Bombay	4600	17 56 N.	73 39 E.	1	185·16	Phil. Trans., 1850, p. 354
27	Magelang, Java	1256	7 29 S.	110 13 E.	1	160·04	Bergsma, 1879, p. 220
28	Bojolali, Java	1300	7 32 S.	110 35 E.	1	151·18	Bergsma, 1879, p. 220
29	Padang, Sumatra	0	0 58 S.	100 25 E.	1	181·39	Bergsma, 1879, p. 222
30	Siboga, Sumatra	0	1 44 N.	98 46 E.	1	172·36	Bergsma, 1879, p. 222
31	Singkel, Sumatra	0	2 17 N.	97 45 E	1	171·22	Bergsma, 1879, p. 222
32	Tandjong Pandan	0	2 45 S.	107 33 E.	1	153·27	Bergsma, 1879, p. 224
33	Sintang, Borneo	....	0 7 N.	111 32 E.	1	149·08	Bergsma, 1879, p. 224
34	Makassar, Celebes	0	5 8 S.	119 24 E	1	152·76	Bergsma, 1879, p. 224
35	Leogane, St. Domingo	....	18 30 N.	72 30 W.	.....	150	Maltebrun's Ge'y, i, p 359
36	Vera Cruz, Mexico	0	19 12 N.	96 9 W	9	183·20	Mayer's Mex., v. 2, p. 188
37	Marmato, N. Grenada	4678	5 33 N.	76 0 W.	2	162·80	Rep. Br. Ass., 1840, p. 116
38	Demerara, Guiana	....	6 45 N.	58 2 W.	.....	156·72	Berghaus, Phys. Atlas
39	Caraccas, Colombia	2730	10 22 N.	67 5 W.	1	155·37	Dove Beiträge, p. 90
40	The Stye, England	1600	54 28 N.	3 13 W.	.....	189·45	Koner, v. 13, p. 105
41	Seathwayte, England	1334	54 29 N.	3 12 W.	.....	152·24	Koner, v. 13, p. 105
42	Kurseong, Bengal	....	26 54 N.	88 18 E.	4	140·67	India, 1878, p. 115
43	Darjeeling, Bengal	6912	27 3 N.	88 18 E.	18–21	118·24	India, 1878, p. 115
44	Mongpoo, Bengal	....	26 58 N.	88 24 E.	5– 6	119·44	India, 1878, p. 115
45	Julpigoree, Bengal	....	26 32 N.	88 50 E.	9–10	124·22	India, 1878, p. 115
46	Cooch Behar, Bengal	....	26 16 N.	89 29 E.	7– 8	129·95	India, 1878, p. 115
47	Chittagong, Bengal	90	22 21 N.	91 50 E.	20–24	103·73	India, 1878, p. 115
48	Noakhally, Bengal	....	22 52 N.	91 14 E.	20–22	107·45	India, 1878, p. 115
49	Silchar, Assam	87	24 48 N.	92 51 E.	21–22	117·54	India, 1878, p. 116
50	Tura, Assam	....	25 27 N.	90 18 E.	8– 9	122·76	India, 1878, p. 116
51	Dibrugarh, Assam	....	27 34 N.	95 2 E.	15–18	114·45	India, 1878, p. 116
52	Shwe Gyen, Burmah	....	18 6 N.	96 46 E.	10	149·16	India, 1878, p. 121
53	Port Blair, Andamans	61	11 41 N.	92 42 E.	11	117·39	India, 1878, p. 121
54	Nancowry, Nicobars	81	8 0 N.	93 46 E.	5– 6	100·85	India, 1878, p. 121
55	Dharmsala, Punjab	....	32 19 N.	76 21 E.	19–20	126·29	India, 1878, p. 112

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
56	Igatpuri, Hyderabad	....	19° 47′ N.	73° 35′ E.	9–16	120·43	India, 1878, p. 117
57	Karwar, Bombay	44	14 45 N.	74 17 E.	17–18	115·54	India, 1878, p. 118
58	Honawar, Bombay	....	14 17 N.	74 30 E.	15–17	140·97	India, 1878, p. 118
59	Vingorla, Bombay	....	15 50 N.	73 40 E.	10–17	114·30	India, 1878, p. 118
60	Ratnagiri, Bombay	108	17 6 N.	73 23 E.	10–22	104·20	India, 1878, p. 118
61	Goa, Bombay	23	15 21 N.	73 56 E.	4	107·04	India, 1878, p. 118
62	Cochin, Madras	11	9 58 N.	76 17 E.	22–23	114·04	India, 1878, p. 120
63	Calicut, Madras	....	11 15 N.	75 32 E.	17–18	116·73	India, 1878, p. 120
64	Tellicherry, Madras	....	11 45 N.	75 32 E.	15–16	128·08	India, 1878, p. 120
65	Cannanore, Madras	....	11 52 N.	75 26 E.	17–18	135·34	India, 1878, p. 120
66	Mangalore, Madras	....	12 52 N.	74 54 E.	20–25	134·04	India, 1878, p. 120
67	Mercara, Mysore	....	12 30 N.	75 50 E.	15	119·94	India, 1878, p. 120
68	Allepy, Madras	30	9 27 N.	76 20 E.	5	113·26	Phil.Trans., 1850, p.358
69	Dodabetta, Madras	8640	11 23 N.	75 47 E.	1	101·24	Phil.Trans., 1850, p.358
70	Kundalla, Bombay	1740	18 40 N.	73 30 E.	2	141·59	Phil.Trans., 1850, p.356
71	Anjarakandy,	....	11 40 N.	75 40 E.	14	123·52	Dove Beiträge, p. 100
72	Tjandjoer, Java	1542	6 49 S.	107 8 E.	1	128·27	Bergsma, 1879, p. 217
73	Soekawana, Java	5062	6 45 S.	107 38 E.	1	117·88	Bergsma, 1879, p. 217
74	Kedong Kebo, Java	148	7 41 S.	110 2 E.	1	134·10	Bergsma, 1879, p. 219
75	Pekalongan, Java	....	6 53 S.	109 40 E.	1	104·37	Bergsma, 1879, p. 219
76	Semarang, Java	13	6 58 S.	110 25 E.	1	101·78	Bergsma, 1879, p. 219
77	Willem Island, Java	1562	7 16 S.	110 24 E.	1	113·16	Bergsma, 1879, p. 219
78	Salatiga, Java	1932	7 20 S.	110 30 E.	1	135·67	Bergsma, 1879, p. 219
79	Djokjokarta, Java	370	7 48 S.	110 21 E.	1	123·90	Bergsma, 1879, p. 221
80	Klatten, Java	692	7 42 S.	110 35 E.	1	110·99	Bergsma, 1879, p. 221
81	Socrakarta, Java	302	7 34 S.	110 49 E.	1	112·41	Bergsma, 1879, p. 221
82	Ngawi, Java	203	7 24 S.	111 26 E.	1	107·95	Bergsma, 1879, p. 221
83	Malang, Java	1476	7 57 S.	112 38 E.	1	136·30	Bergsma, 1879, p. 221
84	Maëssan, Java	1214	8 0 S.	113 50 E.	1	139·41	Bergsma, 1879, p. 223
85	Benkoelen, Sumatra	....	3 47 S.	102 14 E.	1	130·51	Bergsma, 1879, p. 223
86	Tandjong Pinang	....	0 56 N.	104 25 E.	1	123·70	Bergsma, 1879, p. 225
87	Palembang, Sumatra	....	2 59 S.	104 45 E.	1	108·07	Bergsma, 1879, p. 225
88	Muntok, Sumatra	....	2 3 S.	105 9 E.	1	136·50	Bergsma, 1879, p. 225
89	Pontianak, Borneo	....	0 1 N.	109 20 E.	1	130·94	Bergsma, 1879, p. 225
90	Bandjermasin, Borneo	....	3 19 S.	114 35 E.	1	104·05	Bergsma, 1879, p. 225
91	Banda Isle	....	4 32 S.	129 53 E.	1	142·12	Bergsma, 1879, p. 225
92	Flagstaff Mountain	2245	5 25 N.	100 E.	.....	116·21	Berghaus Ph. Atlas
93	Fiji Islands	77	16 38 S.	178 37 E.	5	124·15	Q.J. Met.Soc., v.3, p.265
94	Navigators' Islands	....	13 50 S.	171 44 W.	.....	106	Q.J. Met.Soc., v.5, p.189
95	Hokitiki, New Zealand	....	42 42 S.	170 58 E.	4	111·65	Zeitschrift, v. 6, p. 345
96	Cafeiere du Perou, Gua.	....	16 5 N.	61 45 W.	19	126·74	Dove Beiträge, p. 92
97	Tivoli, San Domingo	....	19 0 N.	70 W.	2	107·47	Dove Beiträge, p. 93
98	Cape Haitien, S. Dom.	....	19 43 N	72 13 W.	.....	127·89	Berghaus Ph. Atlas
99	Grenada, W. Indies	....	12 9 N.	61 48 W.	3	107·73	Dove Beiträge, p. 92
100	Bath, Jamaica	170	18 0 N.	76 25 W.	2	136·46	Q. J. Met. Soc., v.4, p.16
101	Castleton, Jamaica	700	18 9 N.	76 50 W.	4	106·61	Q. J. Met. Soc., v.4, p.16
102	Cinchona, Jamaica	5100	18 3 N.	76 40 W.	4	104·83	Q. J. Met. Soc., v.4, p.16
103	New Castle, Jamaica	3974	18 3 N.	76 44 W.	4	100·01	Q. J. Met. Soc., v.4, p.16
104	Cayenne, Guyana	....	4 56 N.	52 30 W.	6	138·31	An.Met. de France, 1853
105	Paramaribo, Guyana	....	5 45 N.	55 13 W.	5	142·45	Dove Beiträge, p. 90
106	Pernambuco, Brazil	....	8 10 S.	34 51 W.	1	106·07	Dove Beiträge, p. 90
107	Gongo Soco, Brazil	3357	19 58 S.	43 30 W.	2	115·74	Dove Beiträge, p. 94
108	Georgetown, Guyana	....	6 50 N.	58 4 W.	7	100·5	Dove Beiträge, p. 90
109	Cordoba, Mexico	878	18 51 N.	96 54 W.	9	112·9	Haughton, Ph. Geog.
110	Aspinwall, N. Granada	7	9 23 N.	79 53 W.	4	121·44	Schott's Tables, p. 83
111	Glenco, Scotland	....	56 39 N.	5 10 W.	.....	128·51	Koner, v. 13, p. 105
112	Skye, Scotland	....	57 20 N.	6 12 W.	.....	101·50	Koner, v. 13, p. 105

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
113	Coimbra, Portugal	....	40° 13′ N.	8° 25′ W.	.....	118·55	Dove Beiträge, p. 114
114	Freetown, W. Africa	250	8 29 N.	13 10 W.	5	125·80	Zeitschrift, v. 5. p. 122
115	Fernando Po, W. Africa	98	3 46 N.	8 28 W.	4	100·67	Q.J. Met. Soc., v. 2, p. 52
116	Bahr el Abiad, E. Afri.	....	9 N.	30 E.	.....	100·?	Johnston's Africa, p.571
117	Ft. Tongass, Alaska	25	54 46 N.	130 30 W.	2	118·3	Pacific Coast Pilot, p. 26
118	Neeah Bay, Wash. Ter.	40	48 22 N.	124 37 W.	3	123·35	Schott's Tables, p. 79
119	Valdivia, Chili	42	39 57 S.	73 28 W.	19	115·49	Zeitschrift, v. 11, p. 137
120	Mussoore, N. W. Prov.	....	30 25 N.	77 44 E.	14–26	95·21	India, 1878, p. 113
121	Naini Tal, N. W. Prov.	....	29 26 N.	79 36 E.	17–19	81·16	India, 1878, p. 112
122	Dinajpore, Bengal	....	25 36 N.	88 37 E.	19–21	77·18	India, 1878, p. 115
123	Rungpore, Bengal	....	25 44 N.	89 25 E.	18–22	86·67	India, 1878, p. 115
124	Bogra, Bengal	....	24 49 N.	89 26 E.	16–19	81·28	India, 1878, p. 115
125	Burrisal, Bengal	....	22 44 N.	90 20 E.	13–14	78·46	India, 1878, p. 115
126	Mymensing, Bengal	....	24 48 N.	90 30 E.	17–19	98·27	India, 1878, p. 115
127	Comillah, Bengal	....	23 33 N.	91 20 E.	21–22	92·56	India, 1878, p. 115
128	Rangamati, Bengal	....	22 32 N.	92 17 E.	10	97·57	India, 1878, p. 115
129	Agartalla, Bengal	....	23 52 N.	90 20 E.	6–7	77·77	India, 1878, p. 115
130	False Point, Bengal	15	20 20 N.	86 47 E.	12	75·02	India, 1878, p. 116
131	Sibsagar, Assam	332	26 59 N.	94 40 E.	22–24	93·98	India, 1878, p. 116
132	Goalpara, Assam	386	26 11 N.	90 40 E.	17	93·34	India, 1878, p. 116
133	Tezpur, Assam	....	26 44 N.	92 52 E.	21–25	76·06	India, 1878, p. 116
134	Nowgong, Assam	....	26 28 N.	92 45 E.	21–24	81·65	India, 1878, p. 116
135	Shillong, Assam	....	25 30 N.	92 4 E.	12–13	86·93	India, 1878, p. 116
136	Rangoon, Burmah	40	16 46 N.	96 12 E.	9	99·69	India, 1878, p. 120
137	Bassein, Burmah	15	16 4 N.	94 50 E.	9	96·89	India, 1878, p. 120
138	Henzada, Burmah	....	17 45 N.	95 32 E.	8	75·09	India, 1878, p. 120
139	Pachmarhi, Cen. Prov.	3504	22 28 N.	78 28 E.	7– 8	80·93	India, 1878, p. 117
140	Byculla, Bombay	....	18 50 N.	72 49 E.	10–17	82·60	India, 1878, p. 118
141	Esplanade, Bombay	....	18 54 N.	72 49 E.	10–17	77·00	India, 1878, p. 118
142	Tanna, Bombay	....	19 23 N.	72 49 E.	12–21	98·21	India, 1878, p. 118
143	Manantoddy, Madras	....	11 48 N.	76 0 E.	11	91·88	India, 1878, p. 120
144	Galle, Ceylon	40	6 1 N.	80 12 E.	9	91·69	India, 1878, p. 120
145	Colombo, Ceylon	40	6 56 N.	79 50 E.	9	88·82	India, 1878, p. 120
146	Kandy, Ceylon	1650	7 18 N.	80 35 E.	9	81·27	India, 1878, p. 120
147	Newera Elya, Ceylon	6150	7 0 N.	80 42 E.	8–9	99·45	India, 1878, p. 120
148	Quilon, Madras	30	8 54 N.	76 39 E.	5	76·76	Phil. Trans., 1850, p.357
149	Singapore, Malacca	....	1 42 N.	103 50 E.	10	91·66	India, 1878, p. 121
150	Serang, Java	102	6 7 S.	106 8 E.	1	81·02	Bergsma, 1879, p. 217
151	Tangerang, Java	33	6 10 S.	106 40 E.	1	79·41	Bergsma, 1879, p. 217
152	Batavia, Java	23	6 11 S.	106 50 E.	6	78·91	Batavia Obs., p. 64
153	Meester Cornelis, Java	46	6 13 S.	106 54 E.	1	78·78	Bergsma, 1879, p. 217
154	Tegal, Java	0	6 51 S.	109 8 E.	1	95·56	Bergsma, 1879, p. 219
155	Toeban, Java	0	6 52 S.	112 5 E.	1	88·70	Bergsma, 1879, p. 219
156	Modjokerto, Java	95	7 28 S.	112 25 E.	1	96·70	Bergsma, 1879, p. 221
157	Soerabaja, Java	0	7 14 S.	112 44 E.	1	92·64	Bergsma, 1879, p. 221
158	Grissee, Java	0	7 10 S.	112 39 E.	1	91·46	Bergsma, 1879, p. 221
159	Bangkalan, Java	16	7 2 S.	112 44 E.	1	96·74	Bergsma, 1879, p. 221
160	Pamekasan, Java	0	7 10 S.	113 30 E.	1	82·48	Bergsma, 1879, p. 221
161	Soemenep, Java	0	7 3 S.	113 54 E.	1	83·07	Bergsma, 1879, p. 221
162	Pasoeroean, Java	13	7 38 S	112 56 E.	1	75·20	Bergsma, 1879, p. 221
163	Besoeki, Java	7	7 43 S.	113 41 E.	1	83·15	Bergsma, 1879, p. 221
164	Sitoebondo, Java	262	7 41 S.	114 2 E.	1	77·87	Bergsma, 1879, p. 223
165	Banjoewangi, Java	16	8 13 S.	114 23 E.	1	88·50	Bergsma, 1879, p. 223
166	Telok Betong, Sumatra	0	5 26 S.	105 16 E.	1	88·86	Bergsma, 1879, p. 223
167	Solok, Sumatra	1234	0 48 S.	100 40 E.	1	83·11	Bergsma, 1879, p. 223
168	Pajakombo, Sumatra	1630	0 15 S.	100 47 E.	1	83·38	Bergsma, 1879, p. 223

Mean Annual Rain-fall for various stations—Continued.

No	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
169	Medan Poetri, Sumatra	46	3 35 N.	98 41 E.	1	84·41	Bergsma, 1879, p. 225
170	Djambi, Sumatra	0	1 35 S.	103 36 E.	1	96·85	Bergsma, 1879, p. 225
171	Hong Kong, China	....	22 20 N.	114 13 E.	1	79·02	Dove Beiträge, p. 102
172	Canton, China	....	23 15 N.	113 16 E.	.....	77·64	Dove Beiträge, p. 102
173	Manilla, Phil. Is.	69	14 36 N.	120 40 E.	1	76·00	International Bulletin
174	Reunion, Isle Bourbon	131	20 50 S.	55 30 E.	6	79·18	Zeitschrift, v. 9, p. 334
175	Southport, Australia	....	12 44 S.	131 0 E.	1	76·89	Todd, S. Aust., p. 126
176	Kingstown, St. Vincent	....	13 13 N.	61 18 W.	.....	82·78	Dove Beiträge, p. 92
177	St. Vincent, W. I.	....	13 15 N.	61 18 W.	6	78·17	Dove Beiträge, p. 92
178	Martinique, W. I.	....	14 50 N.	61 3 W.	.....	86·93	Gehler's Ph. Wör., v. 7
179	Havana, Cuba	50	23 9 N.	82 28 W.	7	91·37	Dove Beiträge, p. 93
180	Philipsburg, St. Martin	....	18 5 N.	63 3 W.	3	86·32	Schott's Tables, p. 81
181	Stony Hill, Jamaica	1425	18 4 N.	76 49 W.	5	80·53	Q. J. Met. Soc., v.4, p.16
182	Mandeville, Jamaica	2130	18 1 N.	77 32 W.	7	86·58	Q. J. Met. Soc., v.4, p.16
183	Salter's Hill, Jamaica	889	18 19 N.	77 48 W.	5	77·41	Q. J. Met. Soc., v.4, p.16
184	Georgetown, Br. Gu.	....	6 41 N.	58 11 W.	11	95·03	Sandeman's Obs.
185	Tlacotalpam, Mexico	11	18 37 N.	95 39 W.	1	89·10	International Bulletin
186	Rustenburg, Guyana	....	5 N.	55 W.	3	97·38	Schott's Tables, p. 83
187	Mt. Washington, N. H.	6286	44 16 N.	71 16 W.	8	77·23	Signal Service Obs.
188	Cape Hatteras, N. C.	....	35 14 N.	75 30 W.	4	78·40	Signal Service Obs.
189	Catharina, Surinam	....	5 48 N.	56 47 W.	4	77·94	Schott's Tables, p. 83
190	San Antonio, Brazil	....	9 5 S.	64 0 W.	1	91·27	Zeitschrift, v. 15, p. 492
191	Mirador, Mexico	3035	19 13 N.	96 50 W.	8	84·70	Haughton. Ph. Geog.
192	St. Maria, Alps	5936	46 34 N.	8 46 E.	.....	97·76	Koner, v. 13, p. 105
193	Stubenbach, Bavaria	....	49 6 N.	13 23 E.	.....	86·54	Koner, v. 13, p. 105
194	Liknoes, Norway	....	61 30 N.	4 41 E.	.....	85·47	Koner, v. 13, p. 105
195	Cape Palmas, W. Africa	....	4 22 N.	7 44 W.	.....	82·07	Berghaus Ph. Atlas
196	Sierra Leone, W. Africa	....	8 20 N.	13 8 W.	.....	86·26	Dove Beiträge, p. 91
197	Astoria, Oregon	50	46 11 N.	123 49 W.	1	86·35	Schott's Tables, p. 77
198	Fort Stevens, Oregon	....	46 12 N.	123 57 W.	1	85·82	Schott's Tables, p. 77
199	Blockhouse, Oregon	....	44 25 N.	123 30 W.	1	96·29	Schott's Tables, p. 77
200	Sitka, Alaska	20	57 3 N.	135 18 W.	30	81·69	Pacific Coast P., p. 26
201	Marmato, N. Grenada	4836	5 29 N.	76 0 W.	15	90·	Proc. Br. Met. Soc., v. 3
202	Conception, Chili	33	36 46 S.	73 9 W.	2	93·15	Zeitschrift, v. 11, p. 137
203	Corral, Chili	33	39 53 S.	72 W.	3	99·68	Zeitschrift, v. 11, p. 137
204	Puerto Montt, Chili	33	41 30 S.	73 W.	10	96·37	Zeitschrift, v. 11, p. 137
205	Simla, Punjab	6952	31 6 N.	77 12 E.	16–17	70·20	India, 1878, p. 112
206	Mount Abu, Rajputana	....	24 38 N.	72 43 E.	19	62·36	India, 1878, p. 112
207	Debra, N. W. Prov.	2232	30 20 N.	78 8 E.	21	70·76	India, 1878, p. 113
208	Khatmandu, Nepal	....	27 41 N.	85 23 E.	24–28	55·90	India, 1878, p. 114
209	Budwan, Bengal	99	23 14 N.	87 54 E.	18–19	58·58	India, 1878, p. 114
210	Bankoora, Bengal	...	23 15 N.	87 12 E.	21–24	55·31	India, 1878, p. 114
211	Soory, Bengal	....	23 53 N.	87 34 E.	16–19	55·65	India, 1878, p. 114
212	Calcutta, Bengal	18	22 33 N.	88 21 E.	49–50	65·80	India, 1878, p. 115
213	Krishnaghur, Bengal	....	23 24 N.	88 38 E.	15–18	56·37	India, 1878, p. 115
214	Jessore, Bengal	33	23 9 N.	89 7 E.	19–24	68·96	India, 1878, p. 115
215	Berhampore, Bengal	66	24 6 N.	88 17 E.	24–26	55·55	India, 1878, p. 115
216	Maldah, Bengal	....	24 58 N.	88 19 E.	21–23	53·52	India, 1878, p. 115
217	Baulea, Bengal	....	24 26 N.	88 38 E.	20–24	60·00	India, 1878, p. 115
218	Pubna, Bengal	....	24 4 N.	89 19 E.	15–17	68·51	India, 1878, p. 115
219	Dacca, Bengal	....	23 43 N.	90 27 E.	28–30	73·22	India, 1878, p 115
220	Cuttack, Bengal	80	20 29 N.	85 54 E.	18–21	55·60	India, 1878, p 116
221	Pooree, Bengal	....	19 48 N	85 58 E.	21–24	55·26	India, 1878, p. 116
222	Balasore, Bengal	....	21 30 N.	87 0 E.	19–21	66·47	India, 1878, p. 116
223	Gauhati, Assam	....	26 14 N.	91 48 E.	27–30	69·21	India, 1878, p. 116
224	Jubbulpore, C. Prov.	1351	23 9 N.	79 59 E.	33–35	52·32	India, 1878, p. 116

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
225	Colaba, Bombay	37	18° 54′ N.	72° 49′ E.	32–62	74·20	India, 1878, p. 118
226	Palghat, Madras	....	10 46 N.	76 45 E.	16	71·52	India, 1878, p. 120
227	Trevandrum	130	8 30 N.	77 E.	8	69·42	Dove Beiträge, p. 100
228	Onrust, Java	....	6 1 S.	106 46 E.	1	71·42	Bergsma, 1879, p. 217
229	Rembang, Java	....	6 45 S.	111 20 E.	1	67·92	Bergsma, 1879, p. 219
230	Probolingo, Java	33	7 44 S.	113 13 E.	1	67·84	Bergsma, 1879, p. 221
231	Fort de Kock, Sumatra	3041	0 21 S.	100 28 E.	1	74·53	Bergsma, 1879, p. 223
232	Kotta Radja, Sumatra	....	5 32 N.	95 20 E.	1	53·27	Bergsma, 1879, p. 223
233	Pulo Penang	....	5 25 N.	100 19 E.	.....	65·06	Berghaus' Ph. Atlas
234	Macao, China	....	22 15 N.	113 34 E.	14	69·10	Dove Beiträge, p. 102
235	Tokio, Japan	66	35 43 N.	139 46 E.	8	65·3	Zeitschrift, v. 15, p. 439
236	Petro Paulovsk	40	53 0 N.	158 39 E.	3	61·1	Russian Met. Annalen
237	Brisbane, N. S. W.	....	27 32 S.	153 2 E.	12	50·5	Haughton, Ph. Geog.
238	Sydney, N. S. W.	....	33 52 S.	151 15 E.	33	50·63	Zeitschrift, v. 10, p. 356
239	King's Island, Aust.	135	39 35 S.	144 5 E.	5	58·66	Zeitschrift, v. 7, p. 394
240	Mackay, Queensland	200	21 10 S.	149 5 E.	4	74·84	Q. J. Met. Soc., v. 7, p. 9
241	Napoleonville, N. Cal.	....	21 30 S.	166 0 E.	2	63·39	An. Met. de France, 1867
242	Nelson. N. Zealand	18	41 15 S.	173 18 E.	7	61·60	Zeitschrift, v. 6, p. 345
243	Tarnnaki, N. Zealand	....	39 2 S.	174 5 E.	9	59·44	Zeitschrift, v. 6, p. 345
244	Mongonui, N. Zealand	....	35 42 S.	173 37 E.	4	58·14	Zeitschrift, v. 6, p 345
245	Wellington, N. Zealand	....	41 15 S.	174 45 E.	8	51·60	Zeitschrift, v. 6, p. 345
246	Gando, West Africa	....	10 N.	4 E.	.....	60·	Johnston's Af., p. 568
247	Freetown, W. Africa	....	8 29 N.	13 15 W.	.....	69·	Johnston's Af., p. 568
248	Bambarre, C. Africa	....	4 37 S.	27 52 E.	.....	58·	Johnston's Af., p. 577
249	Zanzibar, East Africa	44	5 45 S.	39 10 E.	5	61·02	Q.J. Met.Soc., v. 6, p. 32
250	Lagos, West Africa	....	7 31 N.	3 28 E.	1	57·56	Zeitschrift, v. 13, p. 416
251	Lenkoran, Caucasus	75	38 44 N.	48 53 E.	7	51·74	Koner, v. 13, p. 105
252	Kutais, Caucasus	....	42 20 N.	42 50 E.	7	58·90	Koner, v. 13, p. 105
253	Redut Kale, Caucasus	....	42 16 N.	41 36 E.	.....	60·36	Koner, v. 13, p. 105
254	Ragusa, Eu. Turkey	....	42 38 N.	18 7 E.	.....	65·71	Koner, v. 13, p. 107
255	Fiume, Austria	....	45 20 N.	14 26 E.	.....	64·96	Koner, v. 13, p. 107
256	Alt Aussee, Alps	....	47 38 N.	13 47 E.	.....	66·22	Koner, v. 13, p. 108
257	Tolmezzo, Alps	....	46 24 N.	13 3 E.	.....	74·65	Koner, v. 13, p. 108
258	Camajore, Italy	....	43 48 N.	10 23 E.	.....	53·42	Koner, v. 13, p. 108
259	Klausthal, Hanover	....	51 48 N.	10 20 E.	.....	56·18	Koner, v. 13, p. 108
260	Isny, Alps	....	47 41 N.	10 3 E.	.....	54·84	Koner, v. 13, p. 108
261	Genoa, Italy	....	44 25 N.	8 56 E.	.....	55·01	Koner, v. 13, p. 168
262	Freudenstadt, Wurt.	....	48 28 N.	8 22 E.	.....	55·95	Koner, v. 13, p. 108
263	Baden, Baden	....	48 45 N.	8 15 E.	.....	56·85	Koner, v. 13, p. 108
264	Chamberry, France	....	45 34 N.	5 53 E.	.....	64·96	Koner, v. 13, p. 108
265	Bougia, Algeria	....	36 40 N.	5 5 E.	.....	51·77	Koner, v. 13, p. 108
266	Bergen, Norway	....	60 23 N.	5 20 E.	.....	72·68	Koner, v. 13, p. 106
267	Bagneres, Pyrenees	....	42 49 N.	0 35 E.	.....	58·66	Koner, v. 13, p. 107
268	Bayonne, Pyrenees	....	43 30 N.	1 30 W.	.....	56·30	Koner, v. 13, p. 107
269	Vergara, Spain	....	43 5 N.	2 18 W.	.....	51·18	Koner, v. 13, p. 107
270	Santiago, Spain	....	42 52 N.	8 23 W.	.....	67·60	Koner, v. 13, p. 107
271	Oporto, Portugal	....	41 9 N.	8 36 W.	.....	57·68	Koner, v. 13, p. 107
272	Amcliffe, England	....	54 10 N.	2 8 W.	.....	59·49	Koner, v. 13, p. 106
273	Galway, Ireland	....	53 17 N.	9 4 W.	.....	50·99	Koner, v. 13, p. 106
274	Thorshavn, Faroe	....	62 2 N.	6 44 W.	.....	61·22	Danish Met. Obs.
275	Faial, Azores	....	37 40 N.	28 50 W.	2	58·70	Zeitschrift, v. 6, p. 411
276	Heart's Content	22	47 53 N.	53 21 W.	2	54·3	Canada Met. Obs.
277	St. Johns, N. F.	150	47 34 N.	52 42 W.	4	51·9	Canada Met. Obs.
278	Glace Bay, N. S.	34	46 12 N.	59 58 W.	2	50·2	Canada Met. Obs.
279	Sydney, N. S.	37	46 8 N.	60 10 W.	4	50·6	Canada Met. Obs.
280	St. John, N. B.	150	45 17 N.	66 3 W.	4	50·2	Canada Met. Obs.
281	Halifax, N. S.	122	44 39 N.	63 36 W.	4	54·3	Canada Met. Obs.

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
282	Perry, Me.	100	45° 0′ N.	67° 6′ W.	9	50·29	Schott's Tables, p. 17
283	Steuben, Me.	50	44 31 N.	67 58 W.	12	53·36	Schott's Tables, p. 17
284	Fayetteville, Vt.	280	42 56 N.	72 40 W.	7	55·17	Schott's Tables, p. 19
285	Southwick, Ms.	265	42 2 N.	72 48 W.	2	52 50	Schott's Tables, p. 21
286	Wallingford, Ct.	133	41 27 N.	72 50 W.	5	52·03	Schott's Tables, p. 23
287	Ceres, Penn.	1440	42 0 N.	78 25 W	4	54·78	Schott's Tables, p. 33
288	Berwick, Penn.	583	41 5 N.	76 15 W.	2½	56·32	Schott's Tables, p. 35
289	Poplar Grove, W. Va.	720	38 20 N.	81 26 W.	3	55·84	Schott's Tables, p. 39
290	Camden, S. C.	275	34 17 N.	80 33 W.	8	50·56	Schott's Tables, p. 41
291	Fulton, S. C.	150	33 40 N.	80 31 W.	7	54·31	Schott's Tables, p. 41
292	Sparta, Ga.	550	33 17 N.	83 9 W.	9	54·11	Schott's Tables, p. 43
293	Culloden, Ga.	825	32 51 N.	84 13 W.	2	64·24	Schott's Tables, p. 43
294	Atlanta, Ga.	1050	33 45 N.	84 18 W.	2	58·43	Schott's Tables, p. 43
295	Ft. Barrancas, Fla.	20	30 21 N.	87 18 W.	8	57·20	Schott's Tables, p. 43
296	Jacksonville, Fla.	14	30 20 N.	81 39 W.	6	52·72	Schott's Tables, p. 43
297	Ft. Brooks, Fla.	20	28 0 N.	82 28 W.	17	53·63	Schott's Tables, p. 43
298	Ft. Pierce, Fla.	30	27 30 N.	80 20 W.	6½	58·02	Schott's Tables, p. 43
299	Ft. Myers, Fla.	50	26 38 N.	82 0 W.	7	56·55	Schott's Tables, p. 43
300	Ft. Dallas, Fla.	20	25 55 N.	80 20 W.	3½	59 04	Schott's Tables, p. 45
301	Huntsville, Ala.	600	34 43 N.	86 46 W.	12	54·88	Schott's Tables, p. 45
302	Greensborough, Ala.	350	32 40 N.	87 34 W.	16	51·67	Schott's Tables, p. 45
303	Monroeville, Ala.	150	31 33 N.	87 25 W.	5	60·89	Schott's Tables, p. 45
304	Mt. Vernon. Ala.	200	31 12 N.	88 2 W.	15	66·14	Schott's Tables, p. 45
305	Columbus, Mis.	227	33 30 N.	88 28 W.	5	57·13	Schott's Tables, p. 45
306	Natchez, Mis.	264	31 34 N.	91 25 W.	18	53·37	Schott's Tables, p. 45
307	Jackson, Mis.	350	32 23 N.	90 8 W.	4	54·60	Schott's Tables, p. 47
308	Monroe, La.	100	32 20 N.	92 10 W.	10	54·00	Schott's Tables, p. 47
309	West Feliciana, La.	96	30 38 N.	91 20 W.	13	61·34	Schott's Tables, p. 47
310	Baton Rouge, La.	41	30 26 N.	91 18 W.	15	60·16	Schott's Tables, p. 47
311	New Orleans, La.	10	29 57 N.	90 1 W.	18	51·03	Schott's Tables, p. 47
312	Nashville, Tenn.	533	36 10 N.	86 49 W.	7	52·02	Schott's Tables, p. 51
313	Washington, Ark.	660	33 44 N.	93 41 W.	22	54·50	Schott's Tables, p. 51
314	Welchfield, O.	1205	41 23 N.	81 12 W.	8½	51·94	Schott's Tables, p. 55
315	Sandwich, Ill.	665	41 31 N.	88 30 W.	7½	50·17	Schott's Tables, p. 61
316	Ft. Towson, Ind. T.	300	34 0 N.	95 33 W.	14	51·08	Schott's Tables, p. 69
317	Camp Gaston, Cal.	----	41 10 N.	123 15 W.	4½	62·20	Schott's Tables, p. 77
318	Meadow Valley, Cal.	4000	40 20 N.	120 15 W.	4½	57·03	Schott's Tables, p. 77
319	Ft. Umpqua, Or.	8	43 42 N.	124 10 W.	6	67·41	Schott's Tables, p. 77
320	Ft. Hoskins, Or.	----	45 2 N.	123 32 W.	6½	66·71	Schott's Tables, p. 77
321	Ft. Yamhill, Or.	----	45 21 N.	123 30 W.	9	55·59	Schott's Tables, p. 77
322	Ft. Cascades, Wash. T.	----	45 39 N.	121 50 W.	3	64·57	Schott's Tables, p. 79
323	Ft. Wrangell, Alaska	30	56 16 N.	132 29 W.	3	60·5	Pacific C. Pilot, p. 26
324	St. Paul Kadiak, Al.	22	57 47 N.	152 20 W.	1	72·9	Pacific C. Pilot, p. 26
325	Matsqui, Br. Col.	50	49 7 N.	122 16 W.	1	61·1	Canada Met. Obs.
326	New Westminster, B.C.	33	49 12 N.	122 53 W.	2	58·4	Canada Met. Obs.
327	Hope, Br. Col.	130	49 23 N.	121 28 W.	2	53·6	Canada Met. Obs.
328	St. George's, Bermuda	123	32 23 N.	64 40 W.	6½	57·31	Schott's Tables, p. 81
329	Nassau, Bahamas	----	25 5 N.	77 21 W.	2	52·3	Dove Beiträge, p. 93
330	Matansas, Cuba	50	23 2 N.	81 38 W.	1	55·29	Schott's Tables, p. 81
331	Tuxpam, Mexico	----	19 0 N.	97 7 W.	1	62·7	Mex. Met. Obs.
332	Frontera, Mexico	12	18 32 N.	92 40 W.	2	72·51	Schott's Tables, p. 81
333	Tortola, W. I.	916	18 20 N.	64 32 W.	-----	65·17	Berghaus' Ph. Atlas
334	Port au Prince, Hayti	171	18 37 N.	72 17 W.	4½	60·96	Schott's Tables, p. 81
335	San Juan, Portorico	----	18 26 N.	65 39 W.	4	55·26	Zeitschrift, v. 9, p. 222
336	Linstead, Jamaica	403	18 7 N.	77 2 W.	2	60·32	Q.J. Met.Soc., v. 4, p. 15
337	Ellerslie, Jamaica	2000	18 3 N.	76 45 W.	2	66·70	Q.J. Met.Soc., v. 4, p. 15
338	Chapelton, Jamaica	----	18 3 N.	77 17 W.	5	56·11	Q.J. Met.Soc., v. 4, p. 15

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
339	Hope, Jamaica	650	18° 2′ N.	76 44 W.	4	50·95	Q.J. Met.Soc., v. 4, p. 15
340	Black River, Jamaica	....	17 58 N.	77 52 W.	5	56·12	Q.J. Met.Soc., v. 4, p. 15
341	Morant Point, Jamaica	....	17 56 N.	76 28 W.	7	64·58	Q.J. Met.Soc., v. 4, p. 15
342	Belize, Cent. Am.	....	17 29 N.	88 13 W.	6	72·35	Schott's Tables, p. 81
343	Pointe a Pitre, Guad.	....	16 16 N.	61 32 W.	19	71·62	Dove Beiträge, p. 92
344	Guatemala. C. Am.	4856	14 38 N.	90 28 W.	4	53·1	Schott's Tables, p. 81
345	Barbadoes, W. I.	....	13 10 N.	59 37 W.	25	57·7	Haughton, Ph. Geog.
346	Near Kingstown, S. V.	....	13 13 N.	60 W.	.....	67·16	Dove Beiträge, p. 92
347	Trinidad, W. I.	...	10 28 N.	60 28 W.	.....	62·92	Berghaus' Ph. Atlas
348	San Jose, Costa Rica	3757	9 56 N.	84 0 W.	14	58·7	Hazen
349	LaBaja, N. Gren.	....	7 22 N.	72 30 W.	6	54·1	Proc. Br. Met. Soc., v. 3
350	Para, Brazil	....	1 25 S.	48 30 W.	1	71·41	Dove Beiträge, p. 90
351	Ciara, Brazil	....	3 52 S.	38 34 W.	28	52·84	Nature, v. 18, p. 384
352	Rio Janeiro, Brazil	....	23 0 S.	43 16 W.	6½	53·06	Dove Beiträge, p. 94
353	Ancud, Chili	49	41 51 S.	73 13 W.	3	52·01	Zeitschrift, v. 11, p. 137
354	Delhi, Punjab	718	28 40 N.	77 16 E.	28–29	27·20	India, 1878, p. 112
355	Lucknow, Oudh	369	26 50 N.	81 0 E.	8–11	41·69	India, 1878, p. 114
356	Benares, N. W. Prov.	267	25 20 N.	83 2 E.	22	39·92	India, 1878, p. 114
357	Surat, Bombay	36	21 13 N.	72 46 E.	10–16	42·74	India, 1878, p. 118
358	Nagpur, C. Prov.	1025	21 9 N.	79 11 E.	31–32	43·43	India, 1878, p. 116
359	Poona, Bombay	2000	18 28 N.	74 10 E.	23	30·41	India, 1878, p. 117
360	Hydrabad	....	17 27 N.	78 40 E.	10	29·27	India, 1878, p. 117
361	Madras	22	13 5 N.	80 17 E.	66	48·51	India, 1878, p. 119
362	Trichinopoly, Madras	275	10 50 N.	78 44 E.	25–27	38·70	India, 1878, p. 119
363	Ajansk, Russia	....	56 27 N.	138 26 E.	4	34·06	Rep. für Met., v.1, p.175
364	Hakodadi, Japan	90	41 47 N.	140 45 E.	4	43·6	Pacific C. Pilot, p. 26
365	Yokohama. Japan	656	35 27 N.	139 40 E.	1	41·7	Annuaire Met.deFrance
366	Zikawei, China	....	31 12 N.	121 26 E.	4	42·21	Bolletino Mens., v. 1
367	Alagir	2000	43 5 N.	44 19 E.	10	38·94	Rep. für Met., v.1,p. 175
368	Constantinople, Turkey	....	41 2 N.	28 58 E.	.....	27·56	Koner, v. 13, p. 108
369	Beirut, Syria	....	33 54 N.	35 29 E.	2	40·5	Jahrb. für Met., 1876
370	Götheborg, Sweden	....	57 44 N.	12 0 E.	.....	32·56	Koner, v. 13, p. 106
371	Aberdeen, Scotland	....	57 9 N.	2 7 W.	.....	29·44	Koner, v. 13, p. 106
372	Edinburgh, Scotland	....	55 57 N.	3 12 W.	.....	27·00	Koner, v. 13, p. 106
373	Manchester, England	....	53 31 N.	2 16 W.	.....	34·06	Koner, v. 13, p. 106
374	Dublin, Ireland	....	53 21 N.	6 16 W.	.....	29·21	Koner, v. 13, p. 106
375	Cork, Ireland	....	51 55 N.	8 26 W.	.....	41·73	Koner, v. 13, p. 106
376	Hamburg, Germany	....	53 33 N.	9 58 E.	.....	28·82	Koner, v. 13, p. 106
377	Utrecht, Holland	....	52 6 N.	5 8 E.	.....	30·40	Koner, v. 13, p. 106
378	Plymouth, England	....	50 22 N.	4 9 W.	.....	44·38	Koner, v. 13, p. 106
379	Brest, France	....	48 22 N.	4 29 W.	.....	28·35	Koner, v. 13, p. 106
380	Rouen, France	....	49 27 N.	1 4 E.	.....	25·59	Koner, v. 13, p. 107
381	Munich, Bavaria	....	48 8 N.	11 35 E.	.....	29·09	Koner, v. 13, p. 108
382	Salzburg, Aust.	....	47 49 N.	13 0 E.	.....	41·77	Koner, v. 13, p. 108
383	Geneva, Switz.	....	46 21 N.	6 32 E.	.....	29·53	Koner, v. 13, p. 108
384	Milan, Italy	....	45 28 N.	9 11 E.	.....	38·04	Koner, v. 13, p. 107
385	Trieste, Austria	....	45 39 N.	13 49 E.	.....	43·90	Koner. v. 13, p. 107
386	Montpelier, France	....	43 35 N.	3 53 E.	.....	29·13	Koner, v. 13, p. 107
387	Lisbon, Portugal	....	38 43 N.	9 10 W.	.....	26·77	Koner, v. 13, p. 107
388	Florence, Italy	....	43 46 N.	11 15 E.	.....	36·73	Koner, v. 13, p. 107
389	Rome, Italy	....	41 54 N.	12 29 E.	.....	30·91	Koner, v. 13, p. 107
390	Naples, Italy	....	40 53 N.	14 14 E.	.....	30·99	Koner, v. 13, p. 107
391	Gibraltar, Spain	....	36 7 N.	5 20 W.	.....	29·73	Koner. v. 13, p. 107
392	Algiers, N. Africa	...	36 52 N.	3 2 E.	.....	31·10	Koner. v. 13, p. 107
393	Gondar, Abyssinia	....	12 36 N.	37 31 E.	.....	37·38	Berghaus' Ph. Atlas
394	Victoria, Nyanza	....	0	33 E.	.....	49·	Johnston's Af., p. 573

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
395	Bangweolo, C. Africa	....	11 ° ′ S.	29 ° ′ E.	2	47·5	Johnston's Af., p. 577
396	Mauritius Is.	....	20 27 S.	57 31 E.	2	32·42	Dove Beiträge, p. 102
397	Port Louis, Mauritius	30	20 10 S.	57 30 E.	13	35·63	Zeitschrift, v. 7, p. 205
398	Tete, South Africa	250	16 10 S.	33 30 E.	1	33·55	Zeitschrift, v. 7, p. 205
399	Port de France, N. Cal.	....	22 20 S.	166 39 E.	2	48·27	An. Met. de France, 1867
400	Maritzburg, Natal	2095	29 30 S.	30 2 E.	10	30·35	Q. J. Met. Soc., v. 7, p. 5
401	Gardenscliffe, Natal	2270	29 38 S.	30 30 E.	13	35·81	Q. J. Met. Soc., v. 7, p. 5
402	Merebank, Natal	30	29 55 S.	30 55 E.	9	44·21	Q. J. Met. Soc., v. 7, p. 5
403	Ottawa, Natal	300	29 38 S.	31 7 E.	10	38·98	Q. J. Met. Soc., v. 7, p. 5
404	Durban, Natal	130	29 50 S.	31 0 E.	7	42·05	Q. J. Met. Soc., v. 7, p. 5
405	King Williamst'n, S.Af.	2100	32 51 S.	27 37 E.	10	28·23	Q. J. Met. Soc., v. 7, p. 5
406	Grahamstown, S. Af.	1800	33 20 S.	26 33 E.	18	28·73	Q. J. Met. Soc., v. 7, p. 5
407	Capetown, S. Af.	50	33 55 S.	18 25 E.	16	26·77	Q. J. Met. Soc., v. 7, p. 5
408	Wynberg, S. Af.	200	34 1 S.	18 28 E.	14	42·65	Q. J. Met. Soc., v. 7, p. 5
409	Somerset, S. Af.	120	34 5 S.	18 52 E.	5	25·01	Q. J. Met. Soc., v. 7, p. 5
410	Simonstown, S. Af.	....	34 12 S.	18 26 E.	7	29·20	Q. J. Met. Soc., v. 7, p. 5
411	Mt. Lofty, S. Aust.	....	34 55 S.	138 51 E.	12	40·99	Zeitschrift, v. 9, p. 202
412	Mt. Barker, S. Aust.	....	35 0 S.	139 3 E.	9	27·33	Zeitschrift, v. 9, p. 202
413	Robetown, S. Aust.	....	37 3 S.	139 42 E.	9	25·44	Zeitschrift, v. 9, p. 202
414	Penola, S. Aust.	....	37 23 S.	140 59 E.	9	30·40	Zeitschrift, v. 9, p. 202
415	Mt. Gambier, S. Aust.	....	37 51 S.	140 53 E.	9	34·29	Zeitschrift, v. 9, p. 202
416	Beechworth, Victoria	1783	36 24 S.	146 24 E.	4½	29·29	Zeitschrift, v. 7, p. 293
417	Ararat, Victoria	1072	37 18 S.	142 54 E.	3	27·12	Zeitschrift, v. 7, p. 293
418	Ballarat, Victoria	1438	37 36 S.	143 54 E.	8½	27·21	Zeitschrift, v. 7, p. 293
419	Gabo Island, Victoria	40	37 36 S.	149 54 E.	2½	34·60	Zeitschrift, v. 7, p. 293
420	Buninyong, Victoria	....	37 42 S.	143 54 E.	3	26·02	Zeitschrift, v. 7, p. 293
421	Camperdown, Victoria	770	38 12 S.	143 12 E.	5⅝	30·48	Zeitschrift, v. 7, p. 293
422	Portland, Victoria	37	38 24 S.	141 36 E.	7	31·97	Zeitschrift, v. 7, p. 293
423	Port Albert, Victoria	30	38 36 S.	146 42 E.	3½	35·59	Zeitschrift, v. 7, p. 293
424	Melbourne, Victoria	121	38 48 S.	145 0 E.	17	27·45	Zeitschrift, v. 7, p. 293
425	Cape Otway, Victoria	300	38 54 S.	143 50 E.	2½	43·62	Zeitschrift, v. 7, p. 293
426	Kent's Group, Is.	280	39 29 S.	147 15 E.	5	30·40	Zeitschrift, v. 7, p. 394
427	Launceston, Tasmania	142	41 27 S.	147 8 E.	3	31·97	Zeitschrift, v. 7, p. 394
428	Swansea, Tasmania	18	42 8 S.	148 5 E.	3	26·97	Zeitschrift, v. 7, p. 394
429	Port Arthur, Tasmania	55	43 9 S.	147 54 E.	5	45·75	Zeitschrift, v. 7, p. 394
430	South Bruni, Tasmania	250	43 30 S.	147 10 E.	5	40 48	Zeitschrift, v. 7, p. 394
431	Stykkisholm, Iceland	....	65 5 N.	22 46 W.	.....	25·85	Danish Met. Obs.
432	Berufiord, Iceland	....	64 40 N.	14 15 W.	.....	40·74	Danish Met. Obs.
433	Reikiavig, Iceland	36	64 9 N.	20 0 W.	7	28·94	Danish Met. Obs.
434	Angra, Azores	....	38 38 N.	27 15 W.	6	42·17	Zeitschrift, v. 6, p. 411
435	St. Michael, Azores	....	37 45 N.	25 15 W.	10	31·40	Dove Beiträge, p. 106
436	Madeira Is.	50	32 30 N.	17 30 W.	4	27·5	Dove Beiträge, p. 106
437	Funchal, Madeira	....	32 28 N.	16 55 W.	16	29·21	Zeitschrift, v. 6, p. 411
438	Teneriffe Is.	1400	28 12 N.	16 39 W.	4	48·3	Spanish Obs.
439	St. Helena Is.	1764	15 55 S.	5 43 W.	.....	47·77	Dove Beiträge, p. 94
440	Godthaab, Greenland	....	64 11 N.	51 46 W.	.....	25 02	Danish Met. Obs.
441	Iviktut, Greenland	....	61 12 N.	48 11 W.	.....	49 37	Danish Met. Obs.
442	Ramah, Labrador	15	58 54 N.	62 59 W.	2	33·05	Canada Met. Obs.
443	York Factory, Hud. B.	55	57 0 N.	92 26 W.	3	29·8	Canada Met. Obs.
444	St. Paul Is., Bering Sea	50	57 7 N.	170 18 W.	5	35·00	Pacific C. Pilot, p. 26
445	Moose Factory, Canada	30	51 16 N.	80 56 W.	2	29·30	Canada Met. Obs.
446	Poplar Heights, Canada	....	50 5 N.	97 50 W.	1	26·3	Canada Met. Obs.
447	Gimli, Canada	723	50 37 N.	96 58 W.	1	26·75	Canada Met. Obs.
448	Quebec, Canada	....	46 48 N.	71 12 W.	6	37·27	Am. J. Sci., v. 12, p. 13
449	Montreal, Canada	....	45 30 N.	73 36 W.	9	41·76	Schott's Tables
450	Marquette, Michigan	....	46 32 N.	87 23 W.	12	33·48	Schott's Tables
451	Duluth, Wisconsin	....	46 48 N.	92 8 W.	8	25·64	Schott's Tables

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
452	St. Paul, Min.	----	44° 55′ N.	93° 5′ W.	5	25·09	Schott's Tables
453	Toronto, Canada	342	43 39 N.	79 23 W.	25	35·17	Schott's Tables
454	Oswego, N. Y.	250	43 28 N.	76 34 W.	8	46·94	Schott's Tables
455	Portland, Me.	187	43 38 N.	70 15 W.	4	48·63	Schott's Tables
456	Boston, Mass.	82	42 22 N.	71 4 W.	32	41·44	Schott's Tables
457	New York City	----	40 42 N.	74 0 W.	24	43·24	Schott's Tables
458	Detroit, Mich.	597	42 24 N.	82 58 W.	29	35·23	Schott's Tables
459	Chicago, Ill.	----	41 52 N.	87 35 W.	8	34·74	Sig. Service Obs.
460	Omaha, Neb.	----	41 16 N.	96 0 W.	2	35·02	Schott's Tables
461	Pittsburgh, Pa.	----	40 32 N.	80 2 W.	11	36·64	Schott's Tables
462	Washington, D. C.	110	38 53 N.	77 1 W.	19	37·96	Schott's Tables
463	Cincinnati, Ohio	----	39 6 N.	84 26 W.	30	44·50	Schott's Tables
464	St. Louis, Mo.	----	38 37 N.	90 15 W.	28	42·18	Schott's Tables
465	Louisville, Ky.	450	38 18 N.	85 52 W.	3	48·12	Schott's Tables
466	Norfolk, Va.	----	36 51 N.	76 19 W.	19	47·04	Schott's Tables
467	Chapel Hill, N. C.	----	35 54 N.	79 17 W.	4	42·71	Schott's Tables
468	Knoxville, Tenn.	1000	35 59 N.	83 54 W.	2	39 76	Schott's Tables
469	Memphis, Tenn.	262	35 8 N.	90 0 W.	9	44·25	Schott's Tables
470	Ft. Gibson, Ind. Ter.	560	35 48 N.	95 7 W.	20	36·37	Schott's Tables
471	Charleston, S. C.	25	32 47 N.	79 56 W.	41	43·51	Schott's Tables
472	Athens, Ga.	870	33 57 N.	83 25 W.	4	36·54	Schott's Tables
473	Vicksburgh, Mis.	350	32 23 N.	90 56 W.	15	48·87	Schott's Tables
474	San Antonio, Tex.	600	29 25 N.	98 25 W.	6	32·93	Schott's Tables
475	Portland, Or.	----	45 30 N.	122 27 W.	3	47·61	Schott's Tables
476	Ft. Humboldt, Cal.	50	40 45 N.	124 10 W.	11	35 92	Schott's Tables
477	Matamoras, Mex.	55	25 52 N.	97 27 W.	6	36·74	Schott's Tables
478	Chihuahua, Mex.	4640	28 38 N.	106 30 W.	3	25·44	Schott's Tables
479	Mazatlan, Mex.	249	23 11 N.	106 0 W.	1	33 64	International Obs.
480	Zacatecas, Mex.	8187	22 44 N.	102 33 W.	1	30·48	Bol. Geog., v. 5, p. 181
481	Lagos, Mex.	6339	21 25 N.	101 40 W.	1	34·12	Bol. Geog., v. 5, p. 181
482	Leon, Mex.	5901	21 6 N.	101 30 W.	1	27·92	Bol. Geog., v. 5, p. 181
483	Patzcuaro, Mex.	7015	19 31 N.	101 31 W.	1	43·72	Bol. Geog., v. 5, p. 181
484	Puebla, Mex.	7112	19 3 N.	98 11 W.	1	36·69	Bol. Geog., v. 5, p. 181
485	Oaxaca, Mex.	5072	17 3 N.	96 40 W.	1	37·44	Bol. Geog., v. 5, p. 181
486	Guadalajara, Mex.	----	21 5 N.	103 4 W.	6	32·90	Revista Clim., v. 1, p. 115
487	Tepic, Mex.	3458	21 22 N.	104 52 W.	7	42 9	Haughton's Ph. Geog.
488	Nassau, N. Prov.	80	25 5 N.	77 21 W.	3	46·75	Schott's Tables
489	St. Thomas, W. I.	----	18 21 N.	64 56 W.	3	35·19	Schott's Tables
490	Content, Jamaica	500	18 21 N.	77 45 W.	2	45·12	Q.J. Met. Soc., v. 4, p. 16
491	Falmouth, Jamaica	----	18 22 N.	77 40 W.	2	35 68	Q.J. Met. Soc., v. 4, p. 16
492	Dawkin's, Jamaica	60	18 3 N.	76 54 W.	4	37·58	Q.J. Met. Soc., v. 4, p. 16
493	Taylor's, Jamaica	60	18 3 N.	76 55 W.	6	44·25	Q.J. Met. Soc., v. 4, p. 16
494	Monaltrie, Jamaica	250	18 1 N.	76 50 W.	5	39·29	Q.J. Met. Soc., v. 4, p. 16
495	Park Camp, Jamaica	220	18 1 N.	76 47 W.	4	48·13	Q.J. Met. Soc., v. 4, p. 16
496	Kingston, Jamaica	40	17 58 N.	76 50 W.	7	39·85	Q.J. Met. Soc., v. 4, p. 16
497	Ashley Hall, Jamaica	75	17 56 N.	77 17 W.	5	43·83	Q.J. Met. Soc., v. 4, p. 16
498	Santa Cruz, W. I.	----	17 45 N.	64 50 W.	22	44·6	Zeitschrift, v. 12, p. 341
499	Antigua, W. I.	----	17 10 N.	61 48 W.	5	47·85	Dove Beiträge, p. 92
500	Curacao Is.	----	12 15 N.	69 20 W.	-----	26·64	Berghaus' Ph. Atlas
501	Bogota, N. Gren.	8958	4 40 N.	74 42 W.	6	43·8	Br. Met. Soc., v. 3, p. 429
502	Salta, LaPlata	4920	24 51 S.	64 51 W.	5	44·98	Zeitschrift, v. 11, p. 137
503	Tucuman, LaPlata	1411	26 50 S.	65 10 W.	1	41·73	Zeitschrift, v. 11, p. 137
504	Cordoba, LaPlata	1240	31 0 S.	63 58 W.	3	30·51	Zeitschrift, v. 11, p. 137
505	Montevideo, LaPlata	46	34 54 S.	56 7 W.	10	43·56	Zeitschrift, v. 11, p. 137
506	Buenos Ayres, LaPlata	102	34 30 S.	58 28 W.	17	34·08	Clima de B. A., p. 466
507	Tahiti, Soc. Is.	----	17 32 S.	149 34 W.	2	47·68	Zeitschrift, v. 4, p. 530

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
508	Turukansk, Siberia	....	65° 45′ N.	90° 5′ E.	1	16·4	Met. Annalen
509	Bogoslovsk, Ural Mt.	650	59 45 N.	59 59 E.	30	15·51	Repertorium für Met.
510	Enisseisk, Russia	265	58 27 N.	92 5 E.	7	14·8	Met. Annalen
511	Blagodat, Ural Mt.	1249	58 17 N.	59 47 E.	2	11·7	Met. Annalen
512	Tobolsk, Russia	355	58 12 N.	68 16 E.	7	17·82	Met. Annalen
513	Nijne Taguilsk, Ural M.	730	57 55 N.	59 53 E.	20	19·11	Repertorium für Met.
514	Irbit, Russia	....	57 41 N.	63 2 E.	6	19·00	Met. Annalen
515	Catherinbourg, Ural Mt.	850	56 48 N.	60 35 E.	31	13 36	Met. Annalen
516	Tomsk, Russia	241	56 30 N.	84 58 E.	4	14·4	Met. Annalen
517	Ischim, Russia	....	56 6 N.	69 27 E.	6½	16·67	Repertorium für Met.
518	Zlatouste, Ural Mt.	1230	55 11 N.	59 45 E.	31	18·11	Repertorium für Met.
519	Omsk, Russia	261	54 58 N.	73 20 E.	2	13·00	Met. Annalen
520	Isalair, Russia	1125	54 15 N.	85 47 E.	4	13·0	Met. Annalen
521	Nikolaiwsk, China	82	53 18 N.	140 45 E.	6	16·3	Met. Annalen
522	Irkutzk, Russia	1514	52 17 N.	104 22 E.	5	17·5	Met. Annalen
523	Orenbourg, Russia	220	51 45 N.	59 6 E.	25	17·67	Met. Annalen
524	Nertschinsk, Russia	2230	51 18 N.	119 36 E.	27	15·38	Met. Annalen
525	Blagoweststhuck, China	....	50 15 N.	127 38 E.	1	13·2	Met. Annalen
526	Chabarawka, China	....	48 28 N.	135 7 E.	1	14·5	Met. Annalen
527	Urga, Mongolia	....	47 55 N.	108 50 E.	2	12·4	Met Annalen
528	Vladivostok, China	86	43 7 N.	131 54 E.	4	13·8	Met. Annalen
529	Taschkent, Tartary	1588	41 20 N.	69 18 E.	5	13·3	Met. Annalen
530	Pekin, China	100	39 53 N.	116 40 E.	22	24·9	Met. Annalen
531	Tientsin, China	....	39 7 N.	117 10 E.	1	19·4	Met. Annalen
532	Shien Sheen, China	....	38 17 N.	117 10 E.	4	21·73	Boll. Mens., v. 1, p. 101
533	Bannu, Punjab	...	33 1 N.	70 40 E.	16–17	13·60	India, 1878, p. 111
534	Shakpur, Punjab	....	32 20 N.	72 24 E.	24–25	14·99	India, 1878, p. 111
535	Jhang, Punjab	....	31 16 N.	72 19 E.	16–17	12·10	India, 1878, p. 111
536	Montgomery, Punjab	....	30 45 N.	73 11 E.	18–19	10·45	India, 1878, p. 111
537	Jodhpore, Rajputana	....	26 15 N.	73 5 E.	5	13·87	India, 1878, p. 111
538	Umarkot, Bombay	...	25 20 N.	69 42 E.	10–14	11·75	India, 1878, p. 111
539	Erinpoora, Rajputana	...	25 13 N.	73 6 E.	11	13·61	India, 1878, p. 111
540	Pitea, Sweden	....	65 19 N.	21 31 E.	.....	16·22	Koner, v. 13, p. 106
541	Hernosand, Sweden	....	62 35 N.	17 53 E.	.....	21·15	Koner, v. 13, p. 106
542	Abo, Russia	....	60 27 N.	22 17 E.	48	23·57	Repertorium für Met.
543	St. Petersburg, Russia	10	59 56 N.	30 18 E.	31	17·67	Repertorium für Met.
544	Stockholm, Sweden	....	59 22 N.	18 0 E.	.....	15·79	Koner, v. 13, p. 106
545	Kostroma, Russia	...	57 45 N.	40 56 E.	11	19·11	Repertorium für Met.
546	Kalmar, Sweden	....	56 37 N.	16 20 E.	.....	12·76	Koner, v. 13, p. 106
547	Libau, Russia	....	56 30 N.	21 1 E.	5	22·85	Repertorium für Met.
548	Kasan, Russia	280	55 47 N.	49 7 E.	16	13·94	Repertorium für Met.
549	York, England	....	53 58 N.	1 5 W.	.....	24·06	Koner, v. 13, p. 106
550	Samara, Russia	....	53 10 N	50 2 E.	10	15·09	Repertorium für Met.
551	Berlin, Prussia	....	52 31 N.	13 21 E.	.....	23·51	Koner, v. 13, p. 108
552	Warsaw, Russia	430	52 13 N.	21 1 E.	33	22·70	Repertorium für Met.
553	Koursk, Russia	700	51 44 N.	36 14 E.	18	16·81	Repertorium für Met.
554	London, England	....	51 30 N.	0 0	.....	24·57	Koner, v. 13, p. 106
555	Bonn, Germany	....	50 42 N.	7 3 E.	.....	23·43	Koner, v. 13, p. 106
556	Prag, Austria	....	50 6 N.	14 23 E.	.....	15·35	Koner, v. 13, p. 106
557	Paris, France	....	48 50 N.	2 20 E.	.....	20·08	Koner, v. 13, p. 106
558	Vienna, Austria	....	48 12 N.	16 20 E.	.....	19·33	Koner, v. 13, p. 106
559	Odessa, Russia	147	46 25 N.	30 44 E.	13	13·08	Repertorium für Met.
560	Toulouse, France	....	43 35 N.	1 26 E.	.....	23·62	Koner, v. 13, p. 106
561	Tiflis, Caucasus	1500	41 41 N.	44 50 E.	24	19·26	Repertorium für Met.
562	Baku, Caucasus	53	40 42 N.	48 53 E.	17	10·06	Repertorium für Met.
563	Palermo, Sicily	....	38 7 N.	13 19 E.	.....	23·58	Koner, v. 13, p. 107
564	Ooromiah, Persia	7334	37 28 N.	45 8 E.	1	21·51	Am. J. Sci., v. 20, p. 256

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
565	Valladolid, Spain	1680	41° 39′ N	4 43′ W.	10	11·97	Anuario del Obs., 1879
566	Albacete, Spain	2251	39 0 N.	1 51 W.	9	13·15	Anuario del Obs., 1879
567	Ciud Real, Spain	2246	38 59 N.	3 55 W.	9	12·44	Anuario del Obs., 1879
568	Sevilla, Spain	98	37 22 N.	6 0 W.	10	12·01	Anuario del Obs, 1879
569	Oran, North Africa	164	35 41 N.	0 39 W.	27	20·60	An. Met. de France
570	Jerusalem, Palestine	2500	31 46 N.	35 13 E.	5	18·83	J. Met. Soc., Oct. 1867
571	Goree, Senegal	----	14 40 N.	17 31 W.	8	21 0	Haughton, Ph. Geog.
572	St. Louis, Senegal	----	15 33 N.	16 30 W.	7	16·06	Zeitschrift, v. 8, p. 348
573	Christiansborg, W. Af.	45	5 35 N.	0 16 W.	9	22·71	Obs. Met., 1829–42
574	St. Paul de Loanda, W. A.	----	8 48 S.	13 13 E.	-----	13·5	Johnston's Af., p. 582
575	O'Halloran Hill S. Aust.	----	27 28 S.	135 30 E.	10	23·50	Zeitschrift, v. 9, p. 202
576	Aliwal, S. Africa	4400	30 43 S.	25 40 E.	14	22·86	Q. J. Met. Soc., v. 7, p. 5
577	Brakfontein, S. Africa	4000	31 40 S.	23 10 E.	7	10·67	Q. J. Met. Soc., v. 7, p. 5
578	Lower Nel's Poort, S. A.	3000	32 14 S.	23 4 E.	6	10·06	Q. J. Met. Soc., v. 7, p. 5
579	Worcester, S. Africa	780	33 40 S.	19 27 E.	13	14·29	Q. J. Met. Soc., v. 7, p. 5
580	Port Elizabeth, S. Af.	180	33 57 S.	25 37 E.	13	24·36	Q. J. Met. Soc., v. 7, p. 5
581	Mossel Bay, S. Africa	100	34 11 S.	22 10 E.	6	16·72	Q. J. Met. Soc., v. 7, p. 5
582	Kooringa, S. Aust.	----	33 42 S.	138 59 E.	11	18·19	Zeitschrift, v. 9, p. 202
583	Kapunda, S. Aust.	----	34 20 S.	139 0 E.	9	18·70	Zeitschrift, v. 9, p. 202
584	Adelaide, S. Aust.	----	34 40 S.	138 46 E.	34	21·38	Zeitschrift, v. 9, p. 202
585	Strathalbyn, S. Aust.	----	35 8 S.	138 57 E.	-----	17·84	Zeitschrift, v. 9, p. 202
586	Fehuca, Victoria	280	36 6 S.	144 48 E.	2	15·95	Zeitschrift, v. 7, p. 293
587	Longerenong, Victoria	464	36 42 S.	142 30 E.	3	17·80	Zeitschrift, v. 7, p. 293
588	Sandhurst, Victoria	779	36 48 S.	144 6 E.	6	24 06	Zeitschrift, v. 7, p. 293
589	Heathcote, Victoria	789	36 54 S.	144 42 E.	6	23·14	Zeitschrift, v. 7, p. 293
590	Castlemain, Victoria	942	37 6 S.	144 18 E.	3	21·22	Zeitschrift, v. 7, p. 293
591	Geelong, Victoria	96	38 12 S.	144 24 E.	3	20·95	Zeitschrift, v. 7, p. 293
592	Goose Island	26	40 18 S.	147 45 E.	5	20·95	Zeitschrift, v. 7, p. 394
593	Swan's Island	106	40 44 S.	148 10 E.	5	22·64	Zeitschrift, v. 7, p. 394
594	Hobarttown, Tasmania	37	42 52 S.	147 21 E.	30	23·05	Zeitschrift, v. 7, p. 394
595	Grimsey, Iceland	----	66 34 N.	18 3 W.	-----	19·87	Danish Met. Obs.
596	Upernivik, Greenland	----	72 47 N.	56 0 W.	-----	11·74	Danish Met. Obs.
597	Kornok, Greenland	---	64 30 N.	51 10 W.	-----	13·02	Danish Met. Obs.
598	St. Michael's, Alaska	30	63 28 N.	161 48 W.	3	11·30	Pacific C. Pilot, p. 26
599	Clinton, Canada	2978	51 6 N.	121 48 W.	1	11·6	Canada Met. Obs.
600	Lilooet, Canada	----	50 42 N.	122 2 W.	2	11·5	Canada Met. Obs.
601	Kamloops, Canada	1150	50 41 N.	120 28 W.	1	12·0	Canada Met. Obs.
602	Spence's Bridge, Can.	760	50 25 N.	121 30 W.	3	10·1	Canada Met. Obs.
603	O. Kanagan, Canada	----	50 23 N.	119 27 W.	1	13·2	Canada Met. Obs.
604	Nicola Lake, Canada	2100	50 16 N.	120 43 W.	2	10·3	Canada Met. Obs.
605	Lytton, Canada	500	50 14 N.	121 37 W.	1	17·2	Canada Met. Obs.
606	Lit. Britain, Canada	----	50 6 N.	96 57 W.	1	18·2	Canada Met. Obs.
607	Rockwood, Canada	----	50 5 N.	97 12 W.	1	20·04	Canada Met. Obs.
608	Winnipeg, Canada	740	49 55 N.	97 7 W.	4	20·1	Canada Met. Obs.
609	Anticosti I., Canada	20	49 24 N.	63 36 W.	4	21·6	Canada Met. Obs.
610	Ft. Lapway, Idaho	----	46 18 N.	116 54 W.	3	17·00	Schott's Tables
611	Ft. Abercrombie, Dak.	----	46 27 N.	96 28 W.	7	17·34	Schott's Tables
612	Ft. Mackinaw, Mich.	728	45 51 N.	84 33 W.	13	23·96	Schott's Tables
613	Ft. Dalles, Oregon	350	45 36 N.	120 55 W.	12	21·74	Schott's Tables
614	Ft. Randall, Dakota	1245	43 1 N.	98 12 W.	9	16 51	Schott's Tables
615	Ft. Laramie, Wyom. T.	4519	42 12 N.	104 31 W.	12	15·16	Schott's Tables
616	Ft. Crook, Cal.	3390	41 6 N.	121 25 W.	8	23·68	Schott's Tables
617	Salt Lake City, Utah	4320	40 46 N.	112 6 W.	6	23·85	Schott's Tables
618	Ft. Riley, Kansas	1300	39 3 N.	96 35 W.	14	23·62	Schott's Tables
619	Sacramento, Cal.	82	38 34 N.	121 28 W.	18	19·56	Schott's Tables
620	San Francisco, Cal.	140	37 48 N.	122 27 W.	13	20·17	Schott's Tables
621	Ft. Massachusetts, Col.	8365	37 32 N.	105 23 W.	5	17·06	Schott's Tables

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
622	Ft. Marcy, N. Mexico	6846	35° 41′ N.	106° 2′ W.	12	16·65	Schott's Tables
623	Ft. Craig, N. Mexico	4576	33 26 N.	107 8 W.	9	11·67	Schott's Tables
624	Ft. Thorn, N. Mexico	4500	32 47 N.	107 21 W.	5	14·63	Schott's Tables
625	Ft. Davis, Texas	4700	30 26 N.	103 37 W.	6	18·71	Schott's Tables
626	Ft. Clark, Texas	1000	29 17 N.	100 25 W.	8	22·38	Schott's Tables
627	Ft. Duncan, Texas	1460	28 42 N.	100 30 W.	10	21·23	Schott's Tables
628	Ft. McIntosh, Texas	806	27 30 N.	99 29 W.	9	17·84	Schott's Tables
629	Ringgold Barracks, Tex.	521	26 23 N.	98 47 W.	10	21·32	Schott's Tables
630	Sombrero, W. I.	45	18 37 N	63 27 W.	2	16·84	Schott's Tables
631	San Louis Potosi, Mex.	6202	22 9 N.	100 58 W.	1	15·7	Boletin de Geog., v. 5
632	Pabellon, Mexico	6314	22 4 N.	102 11 W.	1	17·1	Boletin de Geog., v. 5
633	Honolulu, Sand. Is.	----	21 16 N.	157 59 W.	-----	22·0	Guyot's Ph. Geog.
634	Mexico City	7474	19 25 N.	99 5 W.	14	24·7	Haughton, Ph. Geog.
635	Valparaiso, Chili	151	33 6 S.	71 40 W.	5	13·50	Zeitschrift, v. 11, p. 137
636	Santiago, Chili	1919	33 28 S.	70 48 W.	19	14·10	Zeitschrift, v. 11, p. 137
637	Talca, Chili	344	35 26 S.	71 0 W.	4	19·87	Zeitschrift, v. 11, p. 137
638	Bahia Blanca, LaPlata	62	38 42 S.	61 45 W.	15	17·72	Zeitschrift, v. 11, p. 137
639	Falkland Is.	----	51 41 S.	57 51 W.	3	20·33	Q.J. Met Soc., Oct., 1850
640	Punta Arenas	33	53 12 S.	71 0 W.	8	22·55	Zeitschrift, v. 11, p. 137
641	Yakutsk, Siberia	299	62 2 N.	129 45 E.	-----	9·	Guyot's Ph. Geog.
642	Okhotsk, Siberia	12	59 20 N.	142 40 E.	3	4·53	Pacific C. Pilot, p. 26
643	Barnaoul, Russia	400	53 20 N.	83 57 E.	30	9·05	Repertorium für Met.
644	Akmolinsk, Russia	843	51 12 N.	71 23 E.	5	9·2	Met. Annalen
645	Ssemipalatinsk, Russia	598	50 24 N.	80 13 E.	4	7·7	Met. Annalen
646	Kjachta, Russia	2525	50 20 N.	106 35 E.	2	8·9	Met. Annalen
647	Irgis, Tartary	367	48 37 N.	61 16 E.	9	6·3	Met. Annalen
648	Astrakhan, Russia	55	46 21 N.	48 5 E.	7	4·89	Repertorium für Met.
649	Raimsk, Russia	----	46 4 N.	61 47 E.	1½	5·99	Dove Beiträge, p. 183
650	Fort No. 1, Russia	149	45 46 N.	62 7 E.	4	3·5	Met. Annalen
651	Sevastopol, Russia	160	44 36 N.	33 31 E.	16	9·05	Repertorium für Met.
652	Novo Petrowsk, Russia	100	44 27 N.	50 8 E.	8	5·03	Repertorium für Met.
653	Nakust, Russia	216	42 27 N.	59 37 E.	4	3·1	Met. Annalen
654	Petro Alexandrovsk	326	41 28 N.	61 5 E.	4	2·8	Met. Annalen
655	Aralych, Russia	2600	39 53 N.	44 31 E.	4	6·04	Repertorium für Met.
656	Leh, Kashmir	11538	34 10 N.	77 42 E.	3	1·32	India, 1878, p. 111
657	Dera Ismail Khan	572	32 0 N.	71 5 E.	16–17	9·28	India, 1878, p. 111
658	Multan, Punjab	420	31 10 N.	71 33 E.	21	7·52	India, 1878, p. 111
659	Dera Ghazi Khan	----	30 5 N.	70 49 E.	16–17	7·39	India, 1878, p. 111
660	Muzaffargarh	----	30 4 N.	71 16 E.	18–19	6·36	India, 1878, p. 111
661	Jacobabad, Bombay	185	28 24 N.	68 18 E.	18	4·86	India, 1878, p. 118
662	Shikarpore, Bombay	----	28 0 N.	68 39 E.	14–16	5·43	India, 1878, p. 118
663	Rohri, Bombay	----	27 38 N.	68 55 E.	17–18	6·35	India, 1878, p. 118
664	Sehwan, Bombay	----	26 31 N.	67 48 E.	13–14	8·50	India, 1878, p. 118
665	Hyderabad, Bombay	134	25 25 N.	68 27 E.	12–16	8·28	India, 1878, p. 118
666	Kurrachee, Bombay	49	24 47 N.	67 4 E.	22–23	7·61	India, 1878, p. 118
667	Tatta, Bombay	----	24 46 N.	68 0 E.	10	9·00	India, 1878, p. 118
668	Biscara, Algeria	350	34 51 N.	5 40 E.	-----	8·58	Koner, v. 13, p. 107
669	Bagdad, Turkey	----	33 21 N.	44 22 E.	-----	6·0	Koner, v. 13, p. 107
670	Alexandria, Egypt	623	31 12 N.	29 52 E.	10	8·46	Zeitschrift, v. 12, p. 634
671	Cairo, Egypt	----	30 2 N.	31 15 E.	----	1·31	Arago Melanges, p. 463
672	Keneh, Egypt	----	26 39 N.	32 45 E.	-----	0	Johnston's Af., p. 563
673	Mourzouk, Fezzan	----	25 54 N.	14 12 E.	-----	0	Gehler, v. 7, p. 1251
674	Thebes, Egypt	----	25 43 N.	32 35 E.	-----	0	Wilkinson's Egypt, v. 4
675	Kotree, Sind	----	25 20 N.	68 14 E.	-----	0	Phil. Trans., 1850, p. 361
676	Stuart's Creek, S. Aust.	----	29 44 S.	138 23 E.	1	9·70	Todd's Met. Obs., p. 126
677	Arrowie, S. Aust.	----	30 51 S.	139 55 E.	1	8·99	Todd's Met. Obs., p 126

Mean Annual Rain-fall for various stations—Concluded.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
678	Angorichina, S. Aust.	....	31 ° ' S.	139 ° ' E.	5	8·70	Zeitschrift, v. 9, p. 202
679	Wirrialpa, S. Aust.	....	31 0 S.	139 45 E.	1	9·63	Todd's Met. Obs., p. 126
680	Eucla, S. Aust.	7	31 45 S.	128 59 E.	1	6·37	Todd's Met. Obs., p. 126
681	Kanjaka, S. Aust.	....	32 10 S.	138 25 E.	4	9·65	Zeitschrift, v. 9, p. 202
682	Port Augusta, S. Aust.	....	32 29 S.	137 45 E.	19	8·60	Todd's Met. Obs., p. 126
683	Moorna, N. S. Wales	....	34 5 S.	141 30 E.	1	6·93	Todd's Met. Obs., p. 126
684	Wentworth, N.S. Wales	....	34 5 S.	141 42 E.	1	9·43	Todd's Met. Obs., p. 126
685	Salamanca, Spain	....	41 13 N.	5 43 W.	.....	9·45	Koner, v. 13, p. 107
686	Mascara, Algeria	....	34 40 N.	0 20 W.	1	8·5	An. Met. de France.
687	Tafilet, Algeria	....	30 50 N.	3 39 W.	.....	0	Johnston's Af., p. 562
688	Tatta, North Africa	....	28 39 N.	6 46 W.	.....	0	Gehler, v. 7, p. 1251
689	Ascension Is.	....	7 55 S.	14 28 W.	2	3·3	Charts of Met. Data
690	Jacobshavn, Greenland	....	69 13 N.	50 55 W.	.....	8·42	Danish Obs.
691	Fort Rae, Canada	....	62 40 N.	115 10 W.	1	6·05	Can. Met. Obs., 1875
692	Ft. Colville, Wash. T.	....	48 42 N.	118 2 W.	4	9·83	Schott's Tables
693	Ft. Bridger, Utah	6656	41 20 N.	110 23 W.	6	6·12	Schott's Tables
694	Camp Floyd, Utah	4860	40 13 N.	112 8 W.	2½	7·34	Schott's Tables
695	Ft. Churchill, Nev.	4284	39 17 N.	119 19 W.	2½	5·67	Schott's Tables
696	Ft. Garland, Col.	8365	37 32 N.	105 40 W.	6	6·10	Schott's Tables
697	Tonaquint, Utah	....	37 11 N.	113 50 W.	2½	8·38	Schott's Tables
698	Camp Burgwin, N. Mex.	....	36 26 N.	105 26 W.	6	8 65	Schott's Tables
699	Albuquerque, N. Mex.	5032	35 6 N.	106 38 W.	12	8·12	Schott's Tables
700	Ft. Mojave, Arizona	604	35 6 N.	114 35 W.	2	2·51	Schott's Tables
701	Socorro, N. Mex.	4560	34 10 N.	106 50 W.	2	7·86	Schott's Tables
702	Ft. Conrad, N. Mex.	4576	33 34 N.	107 9 W.	4	6·76	Schott's Tables
703	Ft. Yuma, Cal.	200	32 44 N.	114 36 W.	10	3·46	Schott's Tables
704	Ft. San Diego, Cal.	150	32 42 N.	117 14 W.	13	9·16	Schott's Tables
705	Ft. Fillmore, N. Mex.	3937	32 14 N.	106 15 W.	8	8·42	Schott's Tables
706	Ft. Bliss, Texas	3830	31 47 N.	106 30 W.	8	9·56	Schott's Tables
707	Ft. Quitman, Texas	3710	30 40 N.	105 0 W.	2	6·26	Schott's Tables
708	Cumana	....	10 27 N.	64 15 W.	.....	7·52	Gehler, v. 7, p. 1311
709	Lima, Peru	530	12 0 S.	77 2 W.	.....	0	Arago's Met. Essays
710	Atacama	....	22 36 S.	68 40 W.	.....	0	Mühry Uebersicht, p. 28
711	Copiapo, Chili	82	27 38 S.	70 38 W.	4	0·32	Zeitschrift, v. 11, p. 137
712	La Serena, Chili	82	29 56 S.	71 16 W.	4	0·51	Zeitschrift, v. 11, p. 137
713	Mendosa, La Plata	2559	33 0 S.	69 24 W.	4	6·97	Zeitschrift, v. 11, p. 137

The first column in the table contains the reference number; column second gives the name of the station; column third gives its elevation above the sea expressed in English feet. For many stations the elevation is not given, and where the figure 0 is inserted it is to be understood as signifying that the station is but little elevated above sea-level. Columns four and five give the latitude and longitude of the station from Greenwich; column sixth shows the number of years of observation represented; column seventh shows the mean annual rain-fall expressed in English inches; and column eighth gives the authority for the results. In the last column, India, 1878, stands for Blanford's Report on the Meteorology of India in 1878; Bergsma, 1879, stands for Bergsma's Report on the rain-fall in the East Indian Archipelago for 1879; Haughton Ph. Geog., stands for Haughton's Lectures on Physical Geography;

Koner, stands for Koner's Zeitschrift der Gesellschaft für Erdkunde zu Berlin; Q. J. Met. Soc., stands for Quarterly Journal of the London Meteorological Society; Zeitschrift, stands for Zeitschrift der österreichischen Gesellschaft für Meteorologie; An. Met. de France, stands for Annuaire Meteorologique de la France; Dove Beiträge, stands for Klimatologische Beiträge von H. W. Dove, 1857; Schott's tables, stands for Tables of the precipitation in rain and snow in the United States, by Charles A. Schott, 1872; Repertorium für Met., stands for Repertorium für Meteorologie, Band I., redijirt von Dr. Heinrich Wild. St. Petersburg; Met. Annalen, stands for Annalen der Physikalischen central Observatoriums, St. Petersburg; Bol. Geog., stands for Boletin de la Sociedad de Geografia y Estadistica de la Republica Mexicana; Revista Clim., stands for Revista mensual Climatologica.

Cases of excessive rain-fall.

The rain-fall at Cherapunji (No. 1), is very much greater than at any other known station, and nearly all of this rain falls during the warmer months of the year. In the following table, column second shows the average rain-fall at Cherapunji for each month of the year; column third shows the average direction of the wind at Calcutta, and column fourth shows its average direction at Chittagong, situated at the head of the Bay of Bengal:

	Rain Cherapunji.	Winds Calcutta.	Winds Chittagong.		Rain Cherapunji.	Winds Calcutta.	Winds Chittagong.
Jan.	0·73	N. 38° W.	N. 26° W.	July	133·54	S. 11° E.	S. 42° E.
Feb.	2·76	S. 81 W.	N. 40 W.	Aug.	77·31	S. 17 E.	S. 31 E.
Mar.	7·05	S. 32 W.	S. 60 W.	Sept.	58·01	S. 27 E.	S. 27 E.
April	30·63	S. 3 W.	S. 13 W.	Oct.	14·02	N. 48 W.	N. 19 W.
May	51·09	S. 11 E.	S. 7 W.	Nov.	2·50	N. 17 W.	N. 19 W.
June	114·70	S. 4 E.	S. 30 E.	Dec.	0 11	N. 26 W.	N. 24 W.

Thus we see that ninety-five per cent of the annual rain at Cherapunji falls during the six months from April to September, inclusive; and during these months the average wind at Calcutta and Chittagong is from the south, while during most of the other six months of the year the average wind is from the northwest.

Cherapunji is situated on the Khasi Hills, 200 miles north of Chittagong, and at an elevation of 4125 feet above the sea. When the wind in the Bay of Bengal blows from the south, rain falls almost incessantly on the Khasi Hills; and when the wind changes to the west or northwest, the rain ceases almost entirely. These facts indicate that the rain-fall is due to an upward deflection of the winds as they encounter a range of

mountains, and the precipitation of the vapor is due not to any special coldness of the mountain, but to the cold of elevation; and the extraordinary amount of the rain-fall is due to an unusual combination of circumstances, viz: 1. The high temperature of the air. (During the months, April to September, the mean temperature of the air at Calcutta is 84°·4 F., and at Chittagong, 81° 9.) 2. Its great humidity coming directly from the Indian Ocean. (During the months, April to September, the average relative humidity of the air at Chittagong is 84.) 3. The proximity of the mountains to the ocean and the abruptness of their elevation.

At stations 2 and 3 the rain fall occurs with the same system of winds as at No. 1.

Nos. 4–7 are situated on the west coast of Hindostan, on the range of mountains parallel with the coast, and 98 per cent of all the rain at these stations falls during the five months from June to September, inclusive, during the prevalence of the southwest monsoon.

Nos. 8 to 10 are situated on the island of Java, and the rain is distributed pretty uniformly through the different months of the year. A chain of mountains extends through the center of this island from west to east, with peaks varying in height from 4,000 to 12,000 feet. No. 11 is on the west coast of the island of Sumatra. This island has mountains rising to the height of 14,000 or 15,000 feet. No. 12 is also situated on a mountainous island. The last five stations during half of the year are within the limits of the southeast trade winds, but during the remainder of the year the winds blow from the west or southwest. No. 13 is situated on an island with mountains over 5,000 feet high, and abundant rains occur in all months of the year. No. 14 is near the belt of calms which separate the northeast from the southeast trade winds.

If we institute a similar comparison of the subsequent cases in the table as far as No. 204 we shall find that they may be classified as follows:

1. Stations on the north and east of the Bay of Bengal, where the rain comes almost wholly with the southwest monsoon, viz: Nos. 1–3, 15–21, 42–54, 120–138.

2. Stations on the west and south part of Hindostan and Ceylon (including a few interior stations), where the rain is also confined almost entirely to the southwest monsoon, viz: Nos. 4–7, 22–26, 55–71, 139–148.

3. Islands situated within the tropics (including a few stations in China, Australia and New Zealand), generally having mountains rising to a height of several thousand feet, viz: Nos. 8–13, 27–35, 72–103, 149–183.

4. Stations on the eastern coast of the American continent,

chiefly within the limits of the trade winds, including a few mountain stations somewhat distant from the coast, viz: Nos. 14, 36–39, 104–110, 184–191.

5. Elevated stations in different parts of Europe including the northwest part of England, the west of Scotland, the coast of Portugal, Norway, etc., viz: Nos. 40 and 41, 111–113, 192–194.

6. Stations on the west coast of Africa, including one in the interior, viz: Nos. 114–116, 195 and 196.

7. Stations on the west coast of North America, viz: Nos. 117–119, 197–204.

The table shows 204 stations at which the mean annual rain-fall exceeds 75 English inches. We see that some of these stations are elevated more than 2,000 feet above the sea, and nearly all of them are situated within 100 or 200 miles of elevated mountains, and the rain chiefly occurs when the wind from the ocean is blowing toward these mountains. There appears no room for doubt that the extraordinary rain-fall at most of these stations is due to the influence of the mountains by which the wind is deflected upward to such a height that a considerable portion of the contained vapor is condensed by the cold of elevation.

Cases of deficient rain-fall.

Among the group of cases in the table having a mean annual rain-fall of less than 10 inches, the most remarkable example is No. 689. This station is on a small but mountainous island

Latitude.	Longitude from Greenwich.					
	40° to 35°.	35° to 30°.	30° to 25°.	25° to 20°.	20° to 15°.	15° to 10°.
20° to 18° N.	3	2	1	0	0	*
18 to 16	3	2	1	1	0	*
16 to 14	1	3	2	2	1	*
14 to 12	2	3	3	3	1	*
12 to 10	4	5	6	6	5	*
10 to 8	9	9	12	11	8	4
8 to 6	7	13	17	15	10	12
6 to 4	8	15	17	18	11	8
4 to 2 N.	6	10	15	15	11	4
2 to 0	3	11	7	9	7	2
0 to 2 S.	5	6	5	4	3	0
2 to 4	1	5	6	5	2	0
4 to 6	*	5	4	3	2	1
6 to 8	*	5	2	4	1	1
8 to 10 S.	*	5	3	1	2	1

situated in the middle of the Atlantic Ocean in latitude 7° 55′ S. In order to determine whether the small rain-fall at this station is due to local causes, I have prepared a table showing the distribution of rain in that part of the Atlantic Ocean situ-

ated between the meridians of 10 and 40 degrees west from Greenwich, and between the parallels of 20° N. lat. and 10° S. lat. This table is derived from a work entitled "Meteorological Data," published by authority of the Meteorological Committee of the Royal Society of London, and the figures represent the number of rains corresponding to a hundred observations of the wind reported in the log-books examined.

The stars in the table denote squares covered by land. From this table we see that a little north of the equator, there is a belt several degrees in breadth, within which there is a remarkable persistence of rainy days, and at a distance of a few degrees on each side of this belt, rain rarely occurs. The following table is constructed upon a plan similar to the preceding, and shows for each month of the year the average number of rains corresponding to a hundred wind observations between the meridians of 20° and 30° west from Greenwich.

Rains on the Atlantic Ocean from 20° to 30° West Longitude.

Latitude.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
20° to 18° N.	1	0	0	0	0	0	0	0	2	0	1	1
18 to 16	1	0	0	0	0	0	1	2	4	2	1	1
16 to 14	0	0	0	0	0	0	0	10	4	2	2	1
14 to 12	0	0	0	0	0	0	5	13	9	7	3	1
12 to 10	1	0	0	0	1	2	13	18	14	12	5	1
10 to 9	3	0	0	0	3	8	23	27	22	20	14	5
9 to 8	0	0	0	0	3	20	28	28	20	20	21	6
8 to 7	8	0	0	1	6	28	31	20	18	27	28	16
7 to 6	14	2	1	1	13	30	25	15	17	22	27	23
6 to 5	19	3	8	9	24	26	13	8	18	26	25	21
5 to 4	25	14	16	19	30	23	4	2	15	24	26	18
4 to 3	32	23	19	25	26	18	6	1	8	16	16	16
3 to 2	22	26	26	23	20	8	1	1	2	6	8	6
2 to 1 N.	25	23	18	19	13	2	2	1	0	3	4	5
1 to 0	19	14	12	17	9	0	0	0	0	1	3	6
0 to 2 S.	5	8	10	12	9	1	1	0	0	1	2	2
2 to 4	4	7	10	13	10	5	3	2	0	2	2	2
4 to 6	3	2	6	6	3	5	4	1	2	2	1	0
6 to 8	1	4	8	6	4	2	3	0	4	2	0	0
8 to 10 S.	1	1	0	0	4	4	0	2	6	1	0	0

We see from this table that the center of the belt of rain oscillates from about 2° N. latitude near the close of winter, to 9° N. latitude near the close of summer, and the belt is 6° or 7° in breadth. This belt corresponds to the region of calms between the N.E. and S.E. trade winds where the upward movement of these winds takes place. From these tables, combined with the information derived from Maury's Pilot Charts and from other sources, we learn that in mid-ocean, between the N. E. and S.E. trade winds there is a belt of calms where the rainfall is excessive, but that within the limits of the trade winds, as long as these winds maintain their usual course, rain is of

rare occurrence. Beyond the limits of the trade winds, rains increase in frequency; and in the Atlantic Ocean beyond latitude 45° N. or 40° S. they are as frequent as within the belt of equatorial calms. This statement explains the small rain-fall at the island of Ascension, which lies within the S.E. trades, and we see that a small rain-fall does not prove that the air of the place is dry, but simply that there is no cause sufficient to produce a strong upward movement of the atmosphere. The principle here developed is the most important one which affects the amount of rain-fall at different places, viz: that excessive rain-fall results from an unusually strong and persistent upward motion of the atmosphere, while a deficient rain-fall results mainly from the absence of this upward motion. The atmosphere always contains vapor, even in the midst of deserts, and during periods of unusual drouth, and a strong upward movement of the dryest atmosphere would precipitate a portion of its vapor in the form of rain or snow. This principle affords (in part but not wholly) the explanation of the rainless regions of the globe.

Another cause of deficient rain-fall which is frequently exemplified is this: if by the interposition of a chain of elevated mountains a current of air is forced upward to a great height and its vapor is condensed, when the air subsequently descends upon the other side of the mountain and comes under greater pressure, its temperature is raised and the air becomes very dry. Such an effect is produced by the chain of the Rocky Mountains, as I have shown in my 13th paper. A similar effect is observed wherever there is an extensive movement of the atmosphere over a long chain of elevated mountains. These principles will assist in explaining most of the rain-less districts of the globe. The Great Desert which stretches from the Atlantic Ocean across Northern Africa and Southern Asia to the Indus, is situated within the N.E. trade winds, within which, as we have seen, very little rain falls in the midst of the Atlantic Ocean. The principal rain-belt of Africa corresponds pretty nearly with the rain-belt which we have found on the Atlantic Ocean a little north of the equator, but its latitude is somewhat affected by the position of the ranges of mountains. The Great Desert of Gobi is in part caused by the drying effect of the Himalaya Mountains upon the southwest winds which have traversed them. It is believed however to be due in part to the operation of another principle which may be stated as follows: In order that a strong upward movement of the atmosphere may prevail over any district, it is necessary that the neighboring air should flow freely toward this district. Whatever impedes the flow of air from neighboring regions must obstruct the upward movement at the point first supposed.

Such an effect may be produced by an obstructing range of mountains, and if a district is completely surrounded by ranges of mountains, any strong upward movement of the air over this district seems impossible, unless from currents of air prevailing at an elevation greater than the summits of the surrounding mountains. Spain affords a remarkable example of the operation of this principle. This country is divided by numerous chains of mountains, one of which upon the north and northwest sides condenses the vapor coming in from the ocean, and presents a continuous belt of excessive rain-fall. But between the different ranges of mountains which traverse this country are small table lands almost entirely surrounded by mountain ranges, and these regions are marked by a great deficiency of rain. One of these is in the neighborhood of Salamanca, where the mean rainfall is only 9·45 inches, although at Santiago, distant less than 200 miles, the average annual rain-fall amounts to 67·60 inches. The extreme dryness at Salamanca does not seem to be due entirely to the great rain-fall upon the mountains situated on the western coast, because in many other parts of Europe (e. g. the coast of Norway) a similar rain-fall upon a range of mountains is not accompanied by an equal dryness upon the eastern side of the mountains. The dryness which prevails over the desert of Gobi is doubtless due in a great measure to the extreme precipitation upon the elevated mountains on the southwest, but this effect is aggravated by the influence of the other mountain ranges by which Gobi is almost entirely surrounded. The small rain-fall which prevails on the east side of the Caspian Sea, is in part due to the influence of the Caucasus and other mountains on the southwest; but this effect is aggravated, as in the case of Gobi, by the mountains and high lands which enclose this region on every side except the northwest. The small rain-fall in Peru is obviously the effect of the Andes upon the easterly winds which blow over them.

The small rain-fall which prevails in Southern California and from thence northward to Salt Lake, is due to the same causes which have been already explained, but their application is somewhat modified by the physical features of the country. Southern California lies in the same latitude as the northern portion of the Great Desert of Sahara. The prevalent winds here are similar to those near the northern margin of the Sahara, and if a great continent stretched eastward from Southern California without any considerable range of mountains, it is believed that it would show an immense desert similar to the Sahara. The small breadth of the American continent south of latitude 30°, together with the continuous chain of mountains which forms the great back bone of the American conti-

nent, prevents the eastward extension of this desert. But while the chain of the Rocky Mountains limits the desert region on the east, the desert is extended northward to Salt Lake by the influence of the mountain ranges on the east and west sides, operating in the mode already explained in the case of the desert of Gobi.

The following are believed to be the principal causes of excessive rain-fall:

1. The meeting of the northeast and southeast trade winds resulting in a great rain-belt surrounding the globe.

2. The irregular barometric depressions of the middle latitudes. The average track of great barometric depressions is not as distinctly marked by an excess of rain-fall as might be expected; nevertheless storm tracks exhibit a tendency to incline toward districts where the rain-fall is unusually great, e. g. Newfoundland, Iceland, coast of Norway, North Italy, etc.

3. Mountain ranges causing increased rain-fall on the side from which the prevalent wind proceeds, as shown on pages 16–18.

4. Proximity to the ocean, especially when the prevalent wind comes from the ocean, e. g. Western Europe; eastern coast of South America, Africa and Australia.

5. Capes and headlands projecting considerably into the ocean generally receive a greater rain-fall than neighboring districts, e. g. Cape Hatteras, Newfoundland, southwest coast of Ireland and England, Cape of Good Hope, etc.

The following are some of the causes of deficient rain-fall:

1. A nearly uniform direction of the winds throughout the year, such as prevails within a portion of the system of the trade winds, especially in mid-ocean, and to some extent over the continents; e. g. Ascension Island, the Sahara, Southern California, South Africa and Australia.

2. The prevalent wind, having passed over a range of elevated mountains, descends upon the leeward side, e. g. desert of Gobi, Tartary, Chili, North America east of the Rocky Mountains, central portion of Spain, etc.

3. Ranges of mountains so situated as to obstruct the free movement of the surface winds toward a central region, e. g. desert of Gobi, Tartary, Southern California, Salamanca in Spain, etc.

4. Remoteness from the ocean measured in the direction from which the prevalent wind proceeds. There is a marked diminution in the mean annual rain-fall as we advance eastward from Western Europe. A similar effect is noticeable in many other parts of the world, but it is generally complicated by the combination of other causes.

5. High latitude. Beyond the parallel of 60° N. latitude, at

a little distance from the ocean, the mean annual rain-fall seldom much exceeds 10 inches; and there are apparently regions of great extent in Asia and North America where the annual rain-fall is less than 10 inches.

When we attempt to explain in detail the peculiarities of the rain-fall in all parts of the world, we find some perplexing cases. The principles above stated naturally lead us to infer that in the United States on the west side of the Alleghany Mountains the rain-fall should be greater than the average, and on the east side it should be less than the average. Schott's map of rain-fall does not indicate such an effect very distinctly, and some may hence conclude that the laws above stated cannot be general. It may be urged in reply that the slope of these mountains is generally quite gradual, and that the effect of elevation is less than it would be if the ascent were more precipitous; also that the proximity to the ocean probably balances in some degree the deficiency of rain-fall which would otherwise exist on the eastern side. Nevertheless it seems incredible that this range should not exert a palpable influence on the amount of the rain-fall, particularly between the parallels of 34° and 38°. Such an influence is somewhat obscurely indicated by Schott's map of rain-fall (1880). That the indications are not more palpable I ascribe to the following circumstances. 1. The observations at the different stations compared were made on different years. 2. The observations were generally made by volunteer observers, and no uniform system of observation was maintained either with respect to the form of the gauge, its height above the ground, freedom of exposure and the mode of measuring the rain and snow; hence as might be expected the observations show excessive anomalies. 3. The stations employed were determined entirely by the convenience of the observers, and their location is not well adapted to indicate the influence of this mountain range. Among all the stations reported in Schott's Tables (1872) the highest one, east of the Mississippi River, is Somerset, Pa. (height 2195 feet); there are four stations of 2000 feet elevation; one of 1720 feet, one of 1530 feet and one of 1502 feet, and these are all the stations (8 in number) whose height exceeds 1500 feet. If a sufficient number of suitable stations were selected, and observations were continued for a few years, it is not doubted that they would show that the Alleghany Mountains exert an appreciable influence on the amount of the annual rain-fall. It is not, however, believed that this influence is as decided as that of the mountains on the northwest coast of America, or those on the coast of Norway. The Alleghany Mountains correspond more nearly to the Ural Mountains in Russia, whose influence upon the rain-fall is small, but nevertheless appreciable.

Mount Washington in New Hampshire exerts a marked influence upon the rain-fall. Here the mean annual precipitation is 77 inches, while in the surrounding districts the mean annual fall is only 40 inches. The general features of the rain-fall in North America conform closely to the principles above enunciated, and it is believed that most of the anomalies which now exist will disappear when we obtain more accurate observations extending over longer periods of time.

The distribution of the rain-fall in Western and Southern Europe presents some peculiarities the cause of which is not very obvious. Throughout a considerable portion of France, including most of the western coast, the annual rain-fall is less than 25 inches, and about Paris it is less than 20 inches. This small rain-fall may be due in part to the small elevation of this district above sea-level, but apparently it is also connected with the average paths of storm centers. Near the coast of Europe, storm centers generally pass north of Scotland; and those which pass south of England appear to incline towards the mountain ranges of North Spain and Switzerland, thereby leaving over France a region where barometric minima are comparatively infrequent. Hungary also is a district of small rain-fall, apparently resulting from the mountain ranges by which it is enclosed.

The small rain-fall at Cumana (No. 708) is apparently due to the high hills which enclose it on all sides except the west. I do not think however that the mean annual rain-fall at Cumana is as small as seven inches. The result given in the table depends solely upon the observations of Humboldt made in 1799, and the rain which he reports all fell in two months, September and October. Probably this does not represent the entire rain-fall of that year, and 1799 may not have been an average year. It is difficult to reconcile some of the statements made with regard to the rain-fall in South America. Humboldt says (vol. vi, p. 789), "in the new continent, the drought of Cumana, Punta Araya and the island of Marguerita can be compared only with the province of Ciara in Brazil, where sometimes (1792–1796) it does not rain during several years." According to a statement in Nature, vol. xviii, p. 385, Ciara (No. 351) is subject to periods of severe drought and also to remarkable floods, but the mean annual rain-fall is 52 inches. I do not question that the average rain-fall at Cumana is small for that latitude, but it does not seem possible that it can be as small as seven inches.

The accompanying map represents pretty well the observations in the preceding catalogue. The chief exceptions are, 1. A few cases of anomalous rain-fall apparently restricted to a small geographical area. 2. A few cases of observations em-

bracing only a short period of time when it was thought that a longer series of observations would cause the anomalies to disappear. If any person whose attention is attracted to this map should discover in it serious defects, he is urgently solicited to communicate to me the observations which indicate these defects. In my next paper I propose to publish all additional observations of rain-fall which I may be able to obtain; and if the present map should be found greatly in error, I intend to issue a revised edition of it.

Art. II.—*Post-Glacial Joints;* by G. K. Gilbert.

The following communication is based upon observations made by the writer as a member of the United States Geological Survey.

The Sevier Desert lies in Utah, immediately south of the Great Salt Lake Desert. Each is a flat, white plain, surrounded by mountains, and each has its salt lake filling its lowest depression. The mountains are all ridges with axes trending north and south, and those which lie between the plains are separated from each other by trough-like valleys through which one may travel from desert to desert without great ascent. During the Glacial Epoch both deserts were covered by water, and the two floods were united by a series of straits so as to make a single lake—the Lake Bonneville of geologists. From this were thrown down a series of fine sediments—clays and marls—which now constitute the floors of the deserts. When the climate changed at the close of the Glacial Epoch the water gradually dried away, and as it fell there came a time when the bottom of the deepest strait was laid bare and the lake was divided into two—the representatives respectively of Great Salt Lake and Sevier Lake. Their separation was not, however, at first complete, for Great Salt Lake fell the more rapidly, and there was a transition epoch during which Sevier Lake overflowed to Great Salt Lake. A channel of outflow was eroded in the lake sediments, cutting them to a depth of more than one hundred feet; and this channel is plainly to be traced at the present time. Indeed it is so conspicuous a topographic feature that it has been named by travelers the "Old River Bed," and a stage station on the old overland road was called "River-bed Station."

One day last summer I stood on a rocky butte which springs from the Salt Lake Desert at its southern margin just at the brink of the Old River Bed. Behind me at the south there were other rocky buttes, and beyond them mountains; and

before me the desert stretched for a hundred miles—a white, glaring plain, interrupted here and there by insular rocky ridges, but for the most part as smooth as a floor and almost as bare. Through it the Old River Bed meandered for twenty miles, a solitary and abandoned water-course. As I gazed my attention was caught by a peculiarity of the farther bank of the river-bed, at a point two miles away. The scant rains of to-day are washing the silt of the plain from either side into the ancient channel, and are at the same time eroding small lateral channels. The peculiarity which attracted my attention was the parallelism and straightness of a group of these small lateral channels, and a brief inspection led to the conviction that their arrangement was too systematic to be fortuitous. Other duties prevented me from making a closer examination, but my companion and assistant, Mr. Israel C. Russell, was enabled to do so the following day, and he found that the details of the drainage were controlled by a compound and extended system of joints. The principal series trend almost precisely north and south and a subordinate series east and west. They all are vertical and straight and (within each series) closely parallel. They are readily traced from top to bottom of the walls of the lateral ravines, and not infrequently a wall exhibits a broad, flat, sheer face caused by the removal of the clay from one side of a plane of jointing. Elsewhere the faces of the bluffs are buttressed by square pilasters, or ornamented by outstanding rectangular columns, the forms of which have been determined by the two systems of joints. The main arroyos leading up from the river-bed are controlled by the main system of joints, but at a short distance back from the bluff there is a tributary drainage at right angles to the primary, and controlled by the cross joints. The edge of the desert plain is thus marked out in a series of rudely rectangular blocks which may be regarded as the incipient stages of the pilasters of the bluff.

The lamination of the clays and marls in which the joints occur is traceable across them, showing that there have been no faults upon their planes; and the absence of faults is quite as strongly attested by the perfect continuity of the even surface of the plain at a little distance from the river-bed.

Mr. Russell's observations showed that they were not restricted to the spot where they were first detected but were discernible generally along the margin of the river-bed. It is impossible to trace them upon the adjacent plain, but there can be little doubt that they extend beneath it. The surface is converted by every shower into a plastic mud and in that condition is welded into continuity and all trace of structure is obliterated. For aught that is known to the contrary they may exist in the lake beds beneath the surface of the entire desert.

The point of especial interest is that these joints have been developed in post-Glacial time within a series of strata not perceptibly indurated, and which repose undisturbed in the place where they were deposited. The strata are nearly horizontal and their inclination of less than one-half a degree, northward, is presumably the original slope of the bottom upon which they were thrown down. Within the basin of the ancient lake there have been small orographic movements since the Glacial Epoch and a few faults are known to have taken place but no evidence has been found of such disturbances in the vicinity of this locality. The lake-basin has been the scene likewise of post-Glacial volcanic eruption but the nearest locality is eighty miles distant from the Old River Bed.

I am not aware that any satisfactory explanation has ever been given of the origin of the jointed structure in rocks and I have none to propose. They have, however, been heretofore associated in my mind first, with induration, and second, with orographic displacement, and their discovery in undisturbed and unindurated rocks was therefore a matter of surprise. The observation is believed to be exceptional and is here published in the hope that it will aid some one specially conversant with the subject in the establishment of the true theory of the origin of the structure.

ART. III.—*On Sound-Shadows in Water;* by JOHN LECONTE.

1. MORE or less perfect Sound-Shadows thrown by hills, buildings, piers, and other obstacles to the transmission of aerial vibrations, must be within the experience of all. Nevertheless, the boundaries of such shadows are so imperfectly defined, that they can hardly be compared, except in a general way, with those of light. Moreover, in some cases, the obstacles placed in the route of the sound-waves, being elastic, propagate, more or less perfectly, the sonorous vibrations of the air through their thickness; so that, under these conditions, it is similar to producing a light-shadow by means of a transparent or translucent body.

2. But even in cases in which the sound-vibrations in air are not sensibly transmitted through the intervening obstacle, the boundaries of the sound-shadows are necessarily very imperfectly defined; for the amount of diffractive divergence proceeding from the secondary waves, originating at the boundaries of the obstacle, and propagated within the geometrical shadow, is usually so considerable, that the diminution of intensity of sound behind it, although quite perceptible, is by no means so conspicuous as might be expected.

3. The contrast, in this respect, between sound and light is well expressed by Lord Rayleigh: "When waves of sound impinge upon an obstacle, a portion of the motion is thrown back as an echo, and under cover of the obstacle there is formed a sort of sound-shadow. In order, however, to produce shadows in anything like optical perfection, the dimensions of the intervening body must be considerable. The standard of comparison proper to the subject is the wave-length of the vibration; it requires almost as extreme conditions to produce rays in the case of sound, as it requires in optics to avoid producing them."* In other words, the difference between sound and light results from the well-known fact, that an ordinary obstacle bears an immense ratio to the length of a wave of light; but does not bear a very great ratio to the length of a sound-wave. Hence it follows from the mathematical theory of undulations, that the waves of sound bend around obstacles, and produce more or less effect within the geometrical shadow; whereas light-shadows have definite boundaries and are more sharply defined. For in the case of light, calculation shows that at any point decidedly within the geometrical projection of the obstacle from the luminous source, the disturbance vanishes, while at any point outside of the geometrical projection, the disturbance is the same as if the primary wave had passed the screen unimpeded. But this is only partially true in the case of ordinary sound-waves, in consequence of their considerable length; it is rigorously true only when, as in optics, the diameter of the obstacle is large in comparison with the wave-length.

4. There are, however, other causes depending upon the differences between the sense of hearing and of sight, which doubtless render the appreciation of the shadows of sound much less distinct than those of light. On this point, Lord Rayleigh justly remarks: "In many cases, sound-shadows appear much less perfect than theory would lead us to expect. The anomaly is due in a great measure, I believe, to an error of judgment, depending on the enormous range of intensity with which the ear is capable of dealing. The whistle of a locomotive is very loud at a distance of ten yards. At a mile off the intensity must be 30,000 times less; but the sound still appears rather loud, and would probably be audible, under favorable circumstances, even when enfeebled in the ratio of a million to one. For this reason, it is not easy to obtain complete shadows."† In other terms, the range of audition is so extensive, that the diffractive secondary waves originating at the boundaries of the obstacle and propagated into the geometrical shadow, though comparatively feeble, produce decided sensuous impressions upon the auditory apparatus of the ear.

* "Theory of Sound," vol. ii, p. 106, art. 283. London, 1878.

† Phil. Mag., 5th series, vol. iii, p. 458, 1877.

5. The mathematical theory of undulations indicates that acoustical shadows should be more distinct for short waves than for long waves. This prevision has been verified by the experiments of Lord Rayleigh; * who found that the sound-shadows cast by acute sounds were more distinct than those produced by grave sounds.

6. Another prevision of theory has been experimentally verified both in the case of light and of sound. It is well known that the great geometer Poisson, in applying Fresnel's integrals to the case of the diffraction of light produced by a small opaque circular disk, was led to the startling result, that the illumination of the center of the shadow was precisely the same as if the disk had been altogether removed. This deduction from theory was experimentally verified by the illustrious Arago, by means of an opaque circular disk of 2^{mm} in diameter; for he observed a bright point in the center of the shadow of the disk on which waves of light were directly incident. In this case, the secondary waves originating at the disk find the conditions of complete concurrence at a definite point in the axis of the geometrical shadow.

7. The difficulties to be overcome, in the experimental verification of the acoustical analogue of this beautiful phenomenon, are entirely different from those of optics, on account of the immense disproportion of wave-lengths. In light, the disk must be small, and the luminous source must have a very small angular magnitude. In sound, the disk must be comparatively large, and the sounds must be acute. Lord Rayleigh has recently succeeded in experimentally verifying this prevision of theory in the case of sound, by means of a circular disk about fifteen inches in diameter, with a bird-call as the source of sound, placed at a distance of twenty inches from the center of the plane of the disk. At twenty-four inches on the farther side of the disk, the augmentation of the intensity of the sound, in the axis of the acoustical shadow, was obvious both to the ear and to a sensitive flame.†

Sound-Shadows in water.

8. It is a significant fact in relation to the phenomenon of acoustical shadows, that they seem to be more perfect or more sharply defined in water than in air. Thus, during the progress of the classical experiments of Daniel Colladon, in November, 1826, on the velocity of sound in the waters of the lake of Geneva, this physicist incidentally observed, that when the end of the hearing-tube (*cornet acoustique*), plunged into the water, was screened from rectilinear communication with the bell by

* Phil. Mag., 5th series, vol. iii, pp. 458, 459, 1877.
† Phil. Mag., 5th series, vol. ix, pp. 281, 282, 1880.

a projecting wall running out from the shore, whose top was above the surface of the lake, there was a very remarkable diminution in the intensity of the sound, in comparison with that observed at a point equally distant from, but in direct communication with, the source of sound, or out of the "acoustic shadow;" thus indicating the relative non-divergence of the rays of sound around obstacles in water, as compared with those in air.*

9. Another fact observed by Colladon during these famous experiments is, in this connection, no less significant. He found that the sound of the bell struck under water, when heard at a distance, has no resemblance to its sound in the air. Instead of a prolonged tone, a short sharp sound is heard, like two knife blades struck together. It was only within 200 meters that the musical tone of the bell was distinguishable after the blow. In air, it is well known the contrary takes place; the shock of the first impulse of the hammer being heard only in the immediate neighborhood of the bell, while the continued musical sound is the only one that affects the hearing at a distance.† Sir John Herschel, in his "Treatise on Sound,"‡ promised to explain this curious difference; but has not, as far as I can find, done so. Colladon § explains this phenomenon by the nature of the sonorous vibrations in water; showing that the duration of the sound will be much less when transmitted by water than when propagated by air.

Experiments of L. I. LeConte in 1874.

10. The preceding remarks show that comparatively few exact observations have been made on the obstruction produced by interposed obstacles to the propagation of sound-waves in different media. The following experimental results in relation to acoustical shadows in water may be of interest to physicists. The experiments were executed in 1874,‖ at my suggestion, by my son, L. I. LeConte, during the engineering operations incident to the removal of "Rincon Rock," a sandstone reef in the harbor of San Francisco (near the southeastern water front of the city), by means of "surface blasting" with "giant powder" or dynamite. The depth of water on the reef was about fifteen feet at low tide, with an extreme tidal range of about six feet. The "cans" or "cartridges" of "giant powder" used contained each about fifteen pounds of the explosive compound, comprising about seventy-five per cent of nitro-glycerine.

* Ann. de Chim. et de Phys., 2d series, vol. xxxvi, pp. 256, 257, 1827.

† Op. cit. supra, p. 254.

‡ Encyc. Metrop., art. 101. § Op. cit. p. 255.

‖ The long delay in writing out the notes of these experiments in form for publication has been due to domestic affliction and the subsequent pressure of perplexing duties.

11. *Effects of the explosive shock.*—It was observed that the suddenness of the shock imparted to the water by this explosive agent produced the most remarkable and astonishing effects. At the distance of 300 feet or more from the detonating cartridge, two distinct shocks were experienced. The first shock came through the intervening water, and was felt as a short concussion or click before there was any sensible elevation of the column of water resting over the point of explosion. The second shock came a little later by the air, and was heard. It was evidently communicated to the air by the water, at the time the elastic pulse transmitted by this liquid (the first shock) emerged, in a direction nearly normal to its surface, over a limited area around a point vertically above the exploding cartridge. This was obvious from the fact that aerial sound came from this region. The area, which was the source of the sound transmitted by the air, was the same as that from which the small jets of water (noticed hereafter, 14) were projected. The gases generated during the explosion came to the surface much later than this shock, and after elevating the column of water, over the position of the cartridge, to the height of twenty-five or thirty feet.

It is the character of the first shock that deserves special notice. To a person sitting in a small boat floating on the water at a distance of 300 feet or more from the point of explosion, with his feet resting on its bottom, the shock was felt as a sudden blow applied to the soles of the feet. In fact, it drove out the oakum from the seams in the bottom of the boat. When the observer stood on the top of a vertical wooden pile, this shock was felt as a sudden concussion coming up from the water along the cylinder of wood. The concussion produced by such an explosion was so violent that it killed or stunned the fish in the water within a radius of 200 or 300 feet from the explosive center. They rose to the surface in a helpless condition, and were secured by the boys.

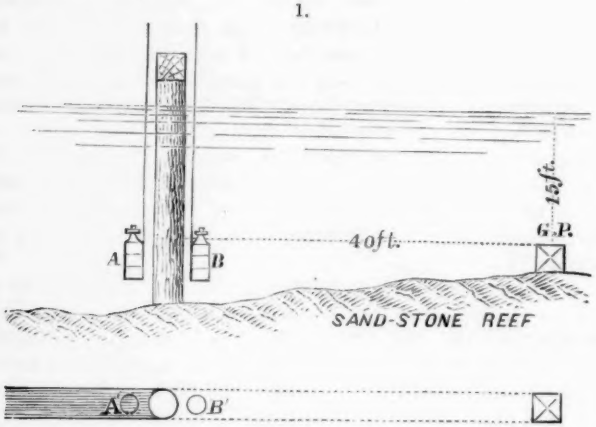
Experiments on Sound Shadows.

12. *Experiments with stout glass (soda-water) Bottles.*—In these experiments the observer stood on the top of a vertical cylindrical pile (the trunk of an Oregon pine) about one foot in diameter, situated about forty feet horizontally from the explosive cartridge. The bottle being secured to a rigid rod was first plunged under the water from ten to twelve inches behind the pile (fig. 1, A), that is, within its geometrical shadow. The shock of the explosion did not injure the bottle. It was then plunged into the water in front of the pile (fig. 1, B), or outside of its geometrical shadow. In this position the bottle was shivered to atoms by the concussion due to the explosion. As

viewed from the experimenter's situation on the top of the pile, fig. 1, A′ and B′, indicate the two positions of the bottle in the preceding experiments.

The experiments were varied by plunging bottles into the water in various positions around the pile, within and outside of its geometrical projection from the explosive center; and in all cases they were protected from injury when within the geometrical shadow, and were shivered when outside of the same. The same results took place whether the bottles were filled with water or with air.

1.



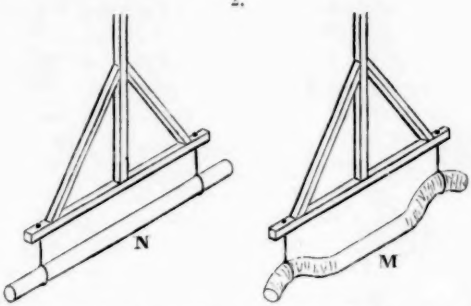
The breaking of a glass vessel, by a sudden shock communicated by means of water, is a fact long known, and is illustrated by the old familiar class experiment of exploding a "Prince Rupert drop" while its bulb is plunged into an ordinary apothecary's phial filled with water.

13. *Experiments with stout glass tubes.*—The cylindrical glass tubes employed were about 6 feet long, and 1·5 inches in diameter, the glass being about 0·5 of an inch in thickness. They were covered by pasting cartridge paper over them, so as to prevent the loss of fragments when breakage occurred. (See fig. 2, M).

The tubes were adjusted to a frame-work of wood so arranged (fig. 2, N) that they could be plunged in a horizontal position beneath the surface of the water behind the pile, the axis of the tube being at right angles to the plane of its shadow, and held there (the observer standing as before on the top), with the middle of the tube in the geometrical shadow, while the two extremities projected on either side about 2·5 feet beyond the boundaries of said shadow. (Fig 3, C and C′). In every

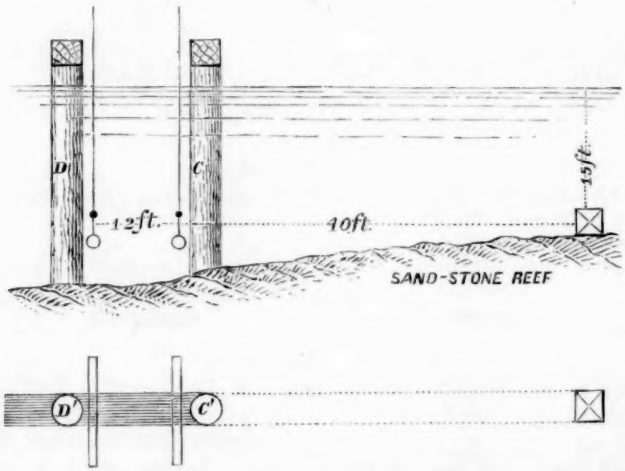
case the shock of the explosion shivered the projecting portions of the tube, and left the portion within the shadow uninjured. The boundaries between the broken and the protected portions of the glass were sharply defined.

2.



By standing on the top of a second pile, in the direction of the axis of the shadow of the first pile, and distant about 12 feet, the experiments were varied by plunging the frame-work and tubes—adjusted at right-angles to the plane of the prolonged shadow—into the water at this distance (12 feet) from

3.



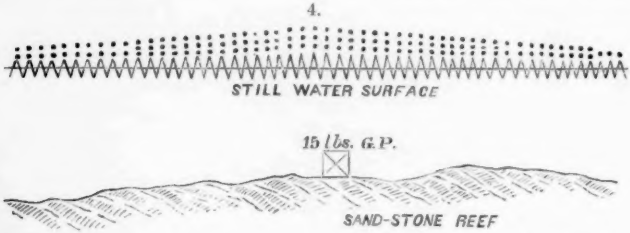
the obstacle which obstructed the sound-wave transmitted by the liquid. (fig. 3, D and D′). The shock of the explosion produced sensibly the same results as when the tube was near to the obstructing obstacle:—the protected portion of the horizontal glass tube was sensibly equal in length to the diameter

of the pile casting the shadow. Hence, the shadow of the cylindrical pile extended back for about 12 feet between sensibly parallel vertical planes, and its boundaries, at this distance, were still sharply defined.

It is evident that, if the explosive center were of insensible magnitude, the horizontal thickness of the geometrical shadow of the pile, at a distance of 12 feet beyond it, would be augmented in the ratio of 40 to 40+12, or of 40 to 52; these numbers being the distances in feet from the center. So that, if the thickness of the shadow at the pile were 12 inches, its thickness at 12 feet beyond would be 15·6 inches. If, however, the explosive energy occupied more or less space (as was the case in relation to the "giant-powder" cartridges), the thickness of the geometrical shadow, or umbra cast by the pile, might not increase sensibly with augmenting distance; and indeed, in case the exploding body exceeded 12 inches in diameter, the thickness of the shadow would diminish with increasing distance from the obstructing pile; as in the case of the umbra cast by an opaque body which is smaller than the luminous source.

14. *Another phenomenon observed.*—Another interesting phenomenon came under notice during the execution of these experiments. It was the singular effects observed on the surface of the water (when perfectly calm and glassy), for a certain area around the point immediately over the exploding cartridge. Simultaneous with the first shock (11) transmitted by the water —and before the ascending gases of explosion disturbed it—the surface of the liquid exhibited numerous jets of water, rising

4.



to the height of about 3 inches over the center of the area, and diminishing in height with augmenting distance from the center. The appearance presented was not unlike that produced by a heavy shower of rain falling on the calm waters of a lake, (fig. 4). To an observer in a boat floating on the adjacent water, and consequently viewing the phenomenon from a point near the water-level, there seemed to be a curious quincunx-like arrangement of the jets.

EXPLANATION OF THE PHENOMENA OBSERVED.

15. *Greater distinctness of Sound-shadows in Water.*—The much greater distinctness of acoustical shadows in water, as compared with those in air, appears to be pretty clearly established by the experiments of Colladon, and the fact seems to be abundantly confirmed by those which we have recorded in the preceding pages. This is an interesting and significant phenomenon in relation to the theory of sound. At first sight, it might be supposed that the difference is due to the greater velocity of propagation of the sound-wave in water. This may have been Sir John Herschel's idea, when he explains Colladon's results by reference to the greater elasticity of water.*

But, as already indicated (3), according to the mathematical theory of undulations the intensity of the effects, due to the secondary waves propagated into the geometrical shadow from the borders of the obstacle, is not directly dependent upon the velocity of propagation, but is properly a function of the wave-length: the diffractive divergence being less for short than for long waves. Hence it follows, that the distinctness of sound-shadows, like those of light, should depend upon the shortness of the wave-lengths. We have already seen (5) that the experiment verifies this prevision of theory in the case of sound-waves in air, by demonstrating that acute sounds cast more distinct shadows than grave sounds. Does this principle apply to sound-shadows in water?

Some physicists have attempted to explain the phenomenon of the great distinctness of sound-shadows in water, as indicated by the observations of Colladon (8), by assuming that the lengths of the sonorous waves propagated through water are much shorter than those transmitted through air.† But no reason is given for this fundamental assumption, other than that it is required by the demands of the theory of undulations, in order to account for the more perfect shadows in water. It evidently would be vastly more philosophical to establish as a matter of fact the greater shortness of the sound-waves in water, and thus to verify the deductions of theory. This we shall endeavor to accomplish.

16. *Measurement of Wave-lengths.*—With regard to continuous or musical sounds, we have the means of very readily determining the wave-length; for it is equal to $\frac{\text{Velocity of Sound}}{\text{Number of Vibrations.}}$ It is evident, therefore, that the number of vibrations or musical pitch of the sonorous body remitting the same, the wave-length in water, so far from being shorter, must be more than four times

* "Treatise on Sound," Encyc. Metrop., art. 102.

† Vide W. H. C. Bartlett's "Elements of Nat. Phil.," "Acoustics and Optics," 4th ed., N. Y. 1866, p. 75, art. 66.

as long as they are in air. Hence, according to theory, if Colladon's observations had been within the radius (200 meters) at which the musical tone of the sonorous bell was heard, the sound-shadows would have been less distinct than in air. Unfortunately, Colladon does not inform us at what distance from the vibrating bell his observations in relation to the acoustical shadows were made, so that it is impossible to apply this critical test of the theory of shadows. But the presumption is, that the observations were made in the neighborhood of Thonon (while the sonorous bell was placed at Rolle), at a distance of 13,487 meters from the source of sound; these being the arrangements during the execution of the experiments for determining the velocity of sound in the waters of the Lake of Geneva. At all distances from the bell greater than 200 meters, as we have seen (9), the sound lost its *musical* character and became short and sharp, like two knife-blades struck together. Hence under the assumption that the observations on sound-shadows were made very far beyond the limits at which musical tones were transmitted, we are precluded from determining the wave-length by the number of vibrations. It appears that in water, grave sounds are more rapidly suppressed or damped than acute sounds: so that at moderate distances from the sonorous center, only the short and sharp sound due to the shock of the striking hammer was transmitted to distant points through the water. It is obvious that the wave-lengths of sounds of this character must be determined by other considerations than those relating to the musical pitch.

In relation to solitary waves generated by sudden blows and explosions,* it may be more difficult to form a just estimate of the wave-length than in the case of musical sounds. Nevertheless it is evident that the wave-length must be directly pro-

* It may be questionable whether the elastic waves generated by momentary explosions or detonations can be properly regarded as strictly solitary. It is possible, that in such cases, groups of waves are generated, similar to those discussed by Lord Rayleigh in the Appendix to his work on the "Theory of Sound." Vol. ii, pp. 297–302.

Furthermore, the admirable and exquisitely refined arrangements devised by Regnault for investigating the phenomena of sound enabled him to submit this question to a more or less satisfactory experimental test, so far as aerial waves are concerned. ("Mémoires de L'Acad. des Sciences," volume xxxvii, pp. 45–49 et pp. 278–282, Paris, 1868.) He found that the explosion of a pistol charged with ordinary powder does not produce a single wave, since it gave rise to a recognizable musical tone of very brief duration (p. 45.); and the same was the case with the sound produced by the detonation of a mixture of oxygen and hydrogen gases (p. 48). But the explosion of a small charge of fulminate of mercury was so sudden that the wave generated in the air was much shorter, and the "coup" was much more "sèc," than that which was produced by a pistol charged with ordinary powder. (pp. 47–48; and pp. 278–281). He adds, "Il est encore difficile de décider si l'on a produit ainsi une onde unique, mais il est certain que si plusieurs ondes prennent naissance, elles doivent se suivre de trés près." (p. 48).

Again, the observations of General H. L. Abbot (U. S. Engineers), incident to

portional to the time occupied by the displacing impulse, multiplied by the velocity of transmission of the elastic pulse. In algebraic terms, if L=wave-length, t=time of the generating impulse, and v=velocity of sound in the elastic medium; we have, L varies as $t \times v$; or $L = t \times v$. Consequently, in a given medium, in which v remains constant, L will be a function of t, or the duration of the generative impulse; so that when the factor t is indefinitely small, the value of L will be correspondingly small. Hence, when the time of the blow or explosive impulse is exceedingly brief, the wave-length must be proportionately short.

17. *Application to Sound-Shadows.*—In the experiments of Colladon, if we assume that the brief shock of the hammer on a limited portion of the bell was alone transmitted to the distant observer, it is clear, that only the short sound-waves thus generated would reach the distant obstructing wall or screen in the water: and consequently, the greater definiteness of the acoustical shadows in water as compared with those in air would be the necessary result of the greater shortness of the sound-waves in water. Under the foregoing assumptions, the theory of undulations appears to afford a satisfactory explanation of the phenomenon observed by Colladon. Nevertheless, it would have been extremely interesting and instructive, as a very severe test of theory, had this distinguished physicist made observations on the relative distinctness of the sound-shadows in the water within the musical range of the submerged bell, as compared with those observed at points so remote that only the sharp blow of the hammer was audible in the water.

In like manner, the application of the principle of briefness of elastic-wave-genesis to the explanation of the phenomena observed by my son in his "Dynamite" experiments, is sufficiently obvious. In fact, all the phenomena incident to the explosion or detonation of the nitro-glycerine compounds indicate that the impulse generated is of indefinitely brief duration; indeed, its suddenness is almost beyond conception. Thus, a dynamite cartridge placed upon a log of wood, unconfined and free, with nothing above it except the atmosphere, will, when exploding, shiver the portion of timber under it to

the heavy blastings at Hallet's Point, Hell Gate, in the harbor of New York, seem to render it at least probable, that the waves transmitted by the earth, reached the different observers in groups, or as a train of waves. (This Journ., vol. xv, (1878), p. 178 et seq.)

Sir G. B. Airy maintains that "there is reason to think that a single wave in air or in the medium of light would not produce the sensation of sound or color." (Undulatory Theory of Optics, p. 15, Art. 18,—1866). No reason is assigned for this somewhat extraordinary assertion. In the case of light it is obviously impossible to experimentally test the validity of this idea of the former Astronomer Royal; and it does not appear to be sustained by the results of acoustical experiments.

atoms:—The detonation being so instantaneous, that the superincumbent air, as well as the gases generated, having no time to be displaced, become a veritable tampon.

The efficiency of surface blasting under water, by means of these explosive compounds, depends upon this extraordinary suddenness of detonation, which renders the effect akin to that of the sudden blow of an enormous unyielding mass. It is evident, that the wave generated in an elastic medium like water, by an explosion of this character, must be very intense and very short. Hence, the acoustical shadow produced by an obstacle placed in its path of propagation, must, as in the case of light, be sharply defined and definite in its boundaries. Thus, the striking fact, that the protecting influence of the piles on the glass vessels plunged in the water was narrowly circumscribed within the limits of the geometrical shadow, may be rationally traced to the extreme shortness of the elastic waves, due to the inconceivably brief duration of action of the generative detonations. This view seems to afford a satisfactory explanation of the remarkable results revealed by the experiments in the harbor of San Francisco.

18. *Gun-powder explosions.*—If the foregoing is the true explanation of the definiteness of the sound-shadows cast in the preceding experiments, then the waves generated by the explosion of ordinary gun-powder, being less sudden, should not produce as sharply defined shadows as those due to the detonation of dynamite. We have, so far as known, no specific experiments testing this point, but it seems to be quite reasonable that such will be found to be the case, whenever the test of experiment is applied. For it is well known that the subaqueous explosions of ordinary powder do not give rise to the remarkable concussions, so characteristic of the detonations of the nitro-glycerine mixtures.

19. *Dynamite explosions in Air.*—Moreover, if my explanation is correct, the acoustical shadows produced by nitro-glycerine detonations in air ought, also, to be more sharply defined than those due to sounds less suddenly generated. In other words, if the distinctness of sound-shadows depends upon the duration of the impulse which produces the accompanying sound-wave, then the definiteness of the shadows cast by sounds propagated through the air should vary with the suddenness of the action of the generating cause.

Inasmuch as the variations in the duration of the genesis of audible sounds in the atmosphere must, in ordinary experience, be very great, it may, at first sight, appear incredible that the corresponding differences in the perfection of sound-shadows cast by obstacles in the paths of different kinds of sounds, should have escaped the most casual observation. But it

must be recollected, that, for the reasons already assigned (1), (2), (3) and (4), aerial acoustical shadows are not readily appreciated by the ear. Moreover, in the case of sounds transmitted by the air, the distinctness of such shadows is most seriously impaired by the numerous reflected waves which come from circumjacent objects. It should be borne in mind, that it is only very recently (5), that the influence of acuteness of sounds on the distinctness of the resulting shadows, has been satisfactorily verified by experiment. In like manner I venture to predict that careful experiments will verify the deduction that the shadows due to sounds generated by the extraordinarily brief detonations of dynamite are more sharply defined, than those owing their origin to sounds less suddenly produced.

In confirmation of the foregoing view, the following observation may be cited: On the 16th of April, 1880, an explosion of about 2000 or 3000 pounds of a nitro-glycerine compound occurred at the "Giant Powder Works," situated under a bluff on the eastern shore of the Bay of San Francisco, at a distance (determined by triangulation), of 16,201 feet (4938 meters), in a direct line, in a northwest direction, from my room in the University building. About twenty-five adult men, a majority of them Chinamen, were literally blown to atoms; no one escaping to reveal the cause of the accident. The concussion at the University buildings,—more than three miles distant,—was sufficient to break about a dozen panes of stout window-glass on the side next to the explosive center. Nearly every person about the University grounds experienced two distinct shocks; one transmitted by the air, and the other by the ground. The cottage occupied by my brother (Professor Joseph LeConte), was situated in the geometrical shadow of one of the buildings; being about 890 feet on the farther side of it. No aerial shock was experienced by him or any member of the household: and the concussion transmitted by the earth was alone felt as a shock emanating from the floor. In other terms, the acoustical shadow cast by the intervening structure completely cut off the sound-wave coming by the air. It is scarcely necessary to add, that for ordinary sounds such would not have been the result.

20. *Phenomenon of Jets.*—The singular phenomenon observed by my son (14), of numerous small jets projected from the surface of the water when the shock transmitted by the liquid reached the surface-area above the exploding cartridge, was probably due to the circumstance that when the short and intense elastic wave emerged in a direction normal or nearly normal to the aqueous surface, the tense superficial capillary film yielded to the sudden impulse more readily at some points

than at others. The sensibly homogeneous character of such a tensile elastic film, would naturally tend to group the points of rupture, or jets of water, into more or less perfect order, partaking more or less of geometrical symmetry. Hence, the curious quincunx-like arrangement of jets as viewed by the observer near the water-level. According to this view, the phenomenon in question seems to find its counterpart or analogue in the more or less symmetrical forms produced by the intersection of the lines of rupture as the result of the tensional strains due to the contraction of homogeneous masses, during the process of cooling or of desiccation. Thus, the columnar structure of certain igneous rocks seems to be due to the tensile stress of contraction by cooling after solidification supervened; while the analogous structure developed by the desiccation of homogeneous masses of moist clay, mud or starch, appears to be produced by a similar strain consequent upon shrinkage from loss of moisture. In a similar manner, the tense superficial capillary film of the water, when it experiences the sudden molecular impulse due to the emergence of elastic pulse, is ruptured along lines more or less symmetrically disposed on the surface of the water; and the liquid beneath is projected through these lines or points of least resistance.

Berkeley, California, October 25th, 1881.

ART. IV. — *On the Connection between the Cretaceous and the recent Echinid Faunæ;* by ALEXANDER AGASSIZ.*

ONE of the very first results clearly indicated by the deep dredgings of Count Pourtalès, and the subsequent investigations of the "Porcupine" expedition, was the antique character preserved by many of the new genera discovered in deep water, and especially their resemblance to Cretaceous genera: and the study of the Challenger Echinids has brought this out still more plainly.

For the purpose of making the comparison of the Challenger Echinids with the earlier Cretaceous types as complete as possible, it will be interesting to take a rapid review of the Cretaceous Echinid fauna, and to contrast it with the abyssal fauna as a whole, independently of its combinations in time with the littoral and continental types, but not independently of its combinations with those types which extend into the abyssal fauna either from the littoral or from the continental fauna.

* From pages 25 to 30 of the Report on the Echinoidea of the Voyage of H. M. S. Challenger, by A. AGASSIZ.

On comparing the genera characteristic of the Chalk with those now found living, we find that a considerable number of the latter date back to the Cretaceous period; and a few of the Cidaridæ, the Echinidæ, the Salenidæ, the Echinoconidæ, and the Petalosticha, even to the earlier epochs, to the Jurassic beds, the Lias and the Trias. The genera *Dorocidaris*, *Phyllacanthus*, *Porocidaris*, *Salenia*, *Podocidaris* (*Magnosia*, *Codiopsis*), *Asthenosoma*, *Phormosoma* (*Echinothuria*), *Temnechinus*, *Cottaldia*, *Phymosoma*, *Holopneustes*, *Hemipedina*, *Echinus*, *Echinocyamus*, *Fibularia*, *Echinolampas*, *Rhynchopygus*, *Conoclypus* (*J.*), *Echinobrissus*, *Catopygus*, *Pygaster*, *Pourtalesia* (*Infulaster*), *Hemiaster*, *Periaster* are in this category, so that a good proportion of the genera of Echinids still living in the present epoch belong to genera already existing at the time of the earliest Cretaceous formations. And leaving out, for the present, the genera which have disappeared during the Tertiary times, we find in the Tertiaries, in addition to the above genera, the following which have continued to the present time: *Arbacia*, *Cœlopleurus*, *Echinometra*, *Stomopneustes*, *Strongylocentrotus*, *Sphærechinus*, *Temnopleurus*, *Trigonocidaris*, *Salmacis*, *Amblypneustes*, *Toxopneustes*, *Hipponoë*, *Clypeaster*, *Echinanthus*, *Laganum*, *Echinarachnius*, *Arachnoides*, *Echinodiscus*, *Mellita*, *Encope*, *Echinonëus*, *Nucleotites*, *Homolampas*, *Paleopneustes*, *Spatangus*, *Maretia*, *Eupatagus*, *Lovenia*, *Breynia*, *Echinocardium*, *Brissopsis*, *Agassizia*, *Brissus*, *Metalia*, *Meoma*, *Linthia*, *Schizaster*, *Moira*.

Leaving, as genera belonging strictly to the present epoch, which, for the present, we may take as the result of the existing condition of things and as the successors of the Cretaceous and of the Tertiary forms, the following only, *Stephanocidaris*, *Goniocidaris*, *Diadema*, *Centrostephanus*, *Echinothrix*, *Astropyga*, *Aspidodiadema*, *Micropyga*, *Colobocentrotus*, *Heterocentrotus*, *Parasolema*, *Pseudoboletia*, *Echinostrephus*, *Pleurechinus*, *Microcyphus*, *Mespilia*, *Prionechinus*, *Evechinus*, *Peronella*, *Astriclypeus*, *Rotula*, *Neolampas*, *Anochanus*, *Palæotropus*, *Cionobrissus*, *Echinocrepis*, *Spatagocystis*, *Cystechinus*, *Argopatagus*, *Palæostoma*, *Tripylus*, *Faovina*.

From our study of the embryonic stages of the Echinidæ, the Clypeastridæ, and the Spatangidæ, and a comparison of these stages with the genera of the Desmosticha and Petalosticha which have either succeeded the genera above mentioned, or have lived with them during the Cretaceous period and have disappeared either during the Cretaceous or the Tertiary periods, we find no difficulty in tracing an unbroken systematic connection from the earliest Cretaceous beds to the present time. But this connection is so complicated, and ramifies in so many directions, that it must be hopeless, even with the small number of species of Echinids known, to attempt to

do more than to indicate the lines of affinities, the delicate threads of which we can trace in characteristics of genera which at any special epoch seem to have little or no structural affinity. Let us take, for instance, the genera characteristic of the Chalk, and attempt to trace their connection both backward and forward in time.

Taking these genera in their most extended signification, and more especially those characteristic of the Lower Cretaceous formations, *Cidaris*, *Orthocidaris*, *Phyllacanthus*, *Tetracidaris*, *Goniopygus*, *Codiopsis*, *Magnosia*, *Cyphosoma*, *Pseudocidaris*, *Orthopsis*, *Pedinopsis*, *Codechinus*, *Stomechinus*, *Acrosalenia*, *Echinothuria*, *Pygaster*, *Discoidea*, *Holectypus*, *Pyrina*, *Clypeopygus*, *Pygurus*, *Metaporhinus*, *Holaster*, *Toxaster*, and comparing them in the first place with the genera of the Lias as far as they are known, we find that, with the exception of *Cidaris* and *Hypodiadema*, the forerunners of the Cidaridæ and Diadematidæ, not a single form of the Echinidæ is represented.

To attempt to explain their relationship to the earlier types, we may say, in a very general way, that the Perischoechinidæ early show, on the one side, a tendency to limit the number of the rows of interambulacral plates; and, on the other side, a decided tendency to a splitting up of the ambulacral and interambulacral plates into numerous irregular rows; they are thus the only group leading directly to such types as Cidaris on the one side, and to the Echinothuridæ on the other, the genera *Tetracidaris* and *Echinothuria* in the Chalk being the representatives of these two groups of Palæechinidæ; while the presence of such a type as *Hypodiadema* early in the Trias may, perhaps, represent the reduction of the number of coronal plates in some as the earlier Echinids, while retaining the uniform tuberculation so characteristic of the Palæechinidæ, and retaining at the same time the proportionally broader ambulacral areas of some of the types. From the time of the Trias, the Cidaridæ have been a most persistent type, and the changes the members of the family have passed through are restricted to very narrow limits, with the exception of the aberrant genera *Heterocidaris*, *Tetracidaris* and *Diplocidaris*, which retain more or less Palæechinoid characters while taking on a more modern facies.

The relationship of the Echinothuridæ to the Palæechinidæ I have already insisted upon elsewhere, and their affinities to the recent Diadematidæ are most close. The relationship of *Hypodiadema* to *Diademopsis*, *Pseudodiadema*, *Hemipedina*, and to the whole group of Pseudodiadematidæ which culminates in the Chalk, and is only very scantily represented at the present day, is sufficiently near not to need any further elucidation. On the other hand, the development of the Echinidæ is some-

what more complicated, as the affinities of the genera from which we trace the development of the Echinidæ, the Arbaciadæ and the Salenidæ, is very close in the Liassic, the Jurassic and the Lower Cretaceous beds; where such types as *Acrosalenia*, *Hemicidaris*, *Glypticus* and *Rhymechinus*, show us how readily we may pass, on the one hand, to the Salenidæ and on the other to the Temnopleuridæ, the Echinidæ and the Arbaciadæ. It is, however, only when the interbranching affinities have not extended in too many directions that we can still easily follow the systematic connection, which is as close as we can possibly desire to have it. In fact it is so extended that we are at a loss to express it satisfactorily.

A few examples will suffice. From the development of *Salenia*, of *Echinus*, of *Temnopleurus*, and of *Arbacia*, we see that these show a very different degree of complication in their systematic relations to the genera which have preceded them in time. The *Saleniæ* retain the simple ambulacral system of the *Cidaridæ*, the small number of coronal plates, the small number of large primary interambulacral tubercles, the variable shape of the primary spines, the secondary papillæ, the large plates of the abactinal system; and, as far as these features in the Cidaridæ are related to the Palæechinidæ, the *Saleniæ* retain to a less degree the Palæechinid affinities of the Cidaridæ. But, in addition to this, we find in the *Saleniæ* the presence of a subanal plate, comparatively large ambulacral tubercles, a slight tendency in the ambulacral pores to deviate from the vertical arrangement of the Cidaridæ, and in the imbricating plates of the actinal membrane are apparently very decidedly different structural features. These last named features are all features which tend toward the Echinidæ proper, and which thus far have not appeared in the older Cidaridæ, though we find some of these characteristics already foreshadowed in the imbricating membrane of the Archæocidaridæ, and in the large primary ambulacral tubercles of the Hemicidaridæ. As far as *Echinus* is concerned, the want of prominence of the principal primary tubercles, as well as greater uniformity in the structure of the spines, recalls again the earliest Palæechinidæ, while the modifications of the ambulacral system also to a certain extent point back to an ambulacral system made up of a large number of plates, as we find most markedly shown again in the more recent Echinometridæ. The actinal membrane is further altered in the direction of that of *Salenia;* we have a smaller number of plates which in some genera are reduced to ten, the supports of the buccal tentacles, which are the only remnants of the former uniform extension of the ambulacral pores as far as the actinosome. In the structure of the apical system, the subanal plates can still be traced in some of the stages of

growth, while in the *Temnopleurus* it never becomes entirely obliterated. In *Temnopleurus* we might say the Salenid abactinal system was more readily traced, and still better in *Arbacia*, while in both these genera the Cidarid features of large primary tubercles is retained in a different degree; and in *Arbacia*, in one part of the ambulacral zone, the arrangement of the pores is of an ancient type, while toward the actinosome its petaloid structure is eminently recent; the structure of the ocular plate of *Arbacia* leads us back directly to the structure of the ocular plate in the oldest Palæechinidæ.

The affinities of the Clypeastridæ with the Discoidæ are clearly indicated by the development of the longitudinal axis, which dates from the exclusion of the anal from the spinal system. We readily trace through *Pileus*, *Holectypus* and *Discoidea* affinities to *Galerites*, and the fossil Conoclypeidæ, while with the appearance of *Galerites*, *Fibularia*, and *Echinocyamus* we have the element of the Clypeastridæ and Scutellidæ; and their relationship to the Cassidulidæ is well shown in the simple ambulacral system of some of the genera, and the rudimentary auricles are still to be traced among the Echinolampadæ, while the affinity of the earliest Cassidulidæ, *Hyboclypus*, *Galeropygus* and the like, to *Pygaster*, which culminate in our day with but slight modifications in *Echinoneus*, show how clearly related the earlier Spatangoids were with the genera to which the Clypeastroids are most closely related, which in their turn will show a most unmistakable relationship to the Desmosticha, so much so that it seems difficult to say whether some of the Echinolampadæ of the present are not more closely related to the Galeritidæ, from the slight development of the pelatoid system, and the presence of jaws or of rudimentary auricles.

Already, in the Jura, *Pygaster* shows the method of the passage of the anal system from the interior of the anal ring to the odd interambulacral space, and we find genera such as *Holectypus* and *Discoidea*, in which it occupies in succession all possible positions between the apical system and a place close to the actinosome; and, the passage once effected in the Clypeastroids, we readily go from a mere circular or elliptical opening placed either in the axis, or obliquely or transversely to it, to an opening in a slight groove or a more or less deep groove occupying this same odd interambulacral space, having its climax in the Echinobrissinæ; and then we most naturally pass to an opening holding a certain relation to a more or less distinct beak which, combined with the subanal plastron enclosed by the subanal fasciole, we can gradually trace from a simple plastron flush with the test, as in the earliest Holasteridæ, to the Echinocardiæ, to the Brissinæ, and finally to the Pourtalesiæ, to a plastron extending as a slight beak below the anal system, and fin-

ally forming a more or less distinct snout; and when this is combined with the deep anal groove of other Spatangoid genera we get the remarkable forms such as we have described as belonging to the Pourtalesiæ.

The type of *Holectypus* with its regular outline, its buccal cuts, the anal system on the actinal surface, and the diminution of the size of the tubercles to uniformity in the two areas, the restriction of the poriferous zone to a single vertical row, all tend to show that the tendency to the Clypeastroids is already highly specialized. The existence of such forms as *Pyrina*, with their simple ambulacra leads directly to the Nucleolidæ and Echinolampadæ. On the contrary, we can only obtain such forms as the present deep sea types from the earlier Cretaceous types like *Infulaster*, and their derivation from such forms as have been figured by Ooster (Echin. Alp. Suisses, pl. x, figs. 1–4) as *Dyaster calceolatus*. (See also de Loriol, Echinoid. Crét. de la Suisse, pl. xxxiii.)

When we take the Spatangoids of the Chalk, they lead us directly through the Palæostominæ and the Collyritidæ to the Ananchytidæ, which have persisted to the present day; and also to the Spatanginæ proper, represented by their few genera, such as *Micraster*, *Hemiaster*, and *Prenaster*, which already possess the structural features characteristic of the recent Spatangoids. That is, we find genera with a peripetalous fasciole, a subanal fasciole, sunken ambulacra, petals of a different degree of development, spines specialized on certain areas of the test, a trace of a sunken anterior groove, of an anal beak, of an actinal plastron, of a snout, of a lateral fasciole, and of a specialization of the primary and secondary tubercles. But, of course, the extent to which these features may be developed in Tertiary and recent genera contrasts often strikingly with the rudimentary nature of the structural features found in the Cretaceous or Tertiary genera. The simple actinostome of the Palæostominæ is combined with a well-marked specialization of the ambulacra above the ambitus, the petaloid feature of the early Spatangoids which appears later in the Cassidulidæ; while in the Ananchytidæ the well developed labium of all the more recent Spatangoidæ is combined with a comparatively more rudimentary state of the ambulacral zones.

Among the Cretaceous genera, *Hemipneustes* and *Ennalaster* are extremely instructive. They show, perhaps better than any others, the passage which exists between the earliest Spatangoids with more or less petaloid ambulacra, and the older Spatangoids without petals, and in which the ambulacra have the same simple structure from the apical system to the actinostome. In both these genera the petaloid structure is limited to the posterior poriferous zone of the lateral ambulacra; the only

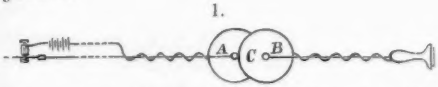
recent genus in which a similar structure still exists is *Agassizia*. In this genus, however, the posterior lateral petals are normally developed, as in other Spatangoids; or perhaps we must consider this as the last trace in normal Spatangoids of the simple condition of the ambulacra, such as we still find it in the Pourtalesiæ. It is specially interesting to compare these genera first to the Ananchytidæ, then to the Toxasteridæ; and finally to such recent genera as *Genicopatagus*, *Homolampas*, *Argopatagus*, and the like. These comparisons lead us to detect affinities in all possible directions, with the highly petaloid ambulacra of the Spatangoids, with the simplest ambulacral petals of the earliest Spatangoids, or with the embryonic ambulacra of the Pourtalesiæ proper.

ART. V.—*Upon an Apparatus for determining without pain to the patient the Position of a Projectile of Lead or other metal in the human body;* by ALEXANDER GRAHAM BELL.*

THE instrument I have the honor of presenting to the Academy has for its object the determination of the exact place occupied by balls of lead, fragments of shell, or metallic substances of any kind embedded in the body of a person wounded by fire-arms, and it may be considered as a form of the well-known Induction Balance of Professor Hughes.

This exploring instrument enables us to determine that position for the most part with very great exactness, and that without any pain to the patient, which is not the case when we use metallic probes which require to be brought into direct contact with the projectile.

1.



The instrument is composed essentially (fig. 1) of a system of two parallel flat coils (A and B) partially superposed upon one another in such a manner that the edge of one is nearly

* This instrument has originated from researches undertaken in the Volta Laboratory at Washington, on the occasion of the sad attempt upon the life of President Garfield. This note is preliminary to a paper which I shall publish shortly, giving a complete account of these researches. It was read before the French Academy.

So many different persons have been kind enough to give me the benefit of their suggestions and advice, concerning the method of exploration for this object, that I can only mention here the names of a few:

Prof. Hughes, George M. Hopkins, Sumner Taintor, Thomas Gleeson, Dr. Chichester A. Bell, Charles E. Buell, Prof. Simon Newcomb, Prof. H. A. Rowland, M. Rogers, Prof. John Trowbridge, J. H. C. Watts, the director of the Western Union Telegraph Co. at Washington, and the correspondent of the New York Tribune at Washington.

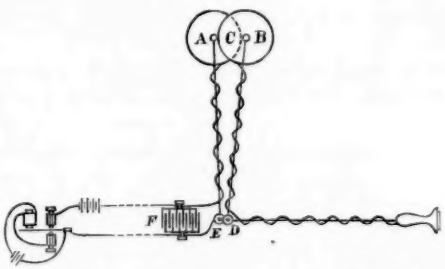
over the axis of the other. One of these coils (A) is made of thick wire constituting a portion of the primary circuit, and the other (B) of thin wire constituting a portion of the secondary circuit. Both coils are embedded in a mass of paraffine placed in the interior of a wooden case furnished with a handle.

A vibratory current from a galvanic battery traverses the primary coil, and the secondary circuit includes an ordinary telephone. Under these circumstances no sound is heard from the telephone, but if we cause any metallic body to approach the part (C) common to the two coils, the silence immediately gives place to a sound, the intensity of which will depend upon the nature of the metallic body, upon its form and upon its distance.

We may remark in this connection that the most favorable form that can be assumed by the projectile for which we explore, is that of a flat disk with its face parallel to the surface of the skin, and that the most unfavorable, a similar disk with its face perpendicular to the same surface.

It is difficult in practice to obtain the exact adjustment of the coils required, and it is therefore found advisable to introduce into the primary and secondary circuits respectively, two other coils (D and E, fig. 2) analogous to the first, but very much

2.



smaller, whose common surface can be modified by the play of a micrometer screw. By means of this fine adjustment we are able easily to reduce the telephone to the most complete silence. It should be added that the effects obtained, when a condenser (F) is introduced into the primary circuit, are much superior to those obtained without, as had been independently predicted by Professor Rowland of the Johns Hopkins University.

If we wish to ascertain the depth at which the metallic mass lies embedded, this is easily ascertained if we know *a priori* its form, its mode of presentation and its substance. It is then only necessary to adjust the apparatus to silence while it is applied to the skin; after which removing the apparatus, we bring near it another metallic mass similar to that explored for

so as to reproduce silence anew, and the distance of this mass from the exploring instrument gives the measure which it is desired to determine.

I conclude this note by relating an experiment made in the office of Dr. Frank Hamilton, of New York, on the 7th of October, last, in the presence of thirteen eminent surgeons.* The experiment was made upon the person of Col. B. F. Clayton, wounded in 1862. The ball entered in front through the left clavicular articulation, breaking the clavicle. Drs. Swineborne and Vanderpool supposed that it was lodged under the scapula, but my apparatus demonstrated on the contrary, that it was located in front and just below the third rib.—*Comptes Rendus*, Paris, Oct. 24, 1881, vol. xciii, p. 625.

ART. VI.—*Observations of the Transit of Mercury*, 1881, *November 7, at Mount Hamilton, California.* (Communicated by the Lick Trustees) by EDW. S. HOLDEN and S. W. BURNHAM.

PROFESSOR HOLDEN and Mr. Burnham were invited by the Lick Trustees to observe the transit of Mercury on the 7th of November, with the smaller instruments which have lately been set up at the Lick Observatory.

Professor Holden observed with a Clark comet-seeker of 4 inches aperture and a power of 50 diameters, the highest available. Captain R. S. Floyd, President of the Lick Trustees, observed with a small telescope, aperture $2\frac{1}{2}$ inches and power 56. Mr. Burnham observed with the 12-inch Clark equatorial (its aperture being reduced to six inches) and a power of 150 diameters. The assumed position of Mount Hamilton is

$$\varphi = +37^\circ\ 21'\ 3''.$$

$$\lambda = +2^h\ 58^m\ 14^s{\cdot}6 \text{ from Washington.}$$

The computed time of first contact is (using the elements of the American Ephemeris), $2^h\ 9^m\ 42^s{\cdot}3$.

The local mean times as observed were,

First Contact.

Holden ..... $2^h\ 11^m\ 2^s{\cdot}3$.
Burnham ..... $2^h\ 10^m\ 41^s{\cdot}1$; H − B = $+21^s{\cdot}2$.

Second Contact.

Holden ..... $2^h\ 12^m\ 25^s{\cdot}8$.
Floyd ..... $2^h\ 12^m\ 15^s{\cdot}0$; H − F = $+10^s{\cdot}8$.
Burnham ..... $2^h\ 12^m\ 5^s{\cdot}7$; H − B = $+20^s{\cdot}1$.

Duration of Ingress.

Holden ..... $1^m\ 23^s{\cdot}5$. | Burnham ..... $1^m\ 24^s{\cdot}6$.

* Drs. G. H. Gardner, G. Durant, Ed. Birmingham, N. Bozeman, L. Damainville, J. N. Hinton, Francis Delafield, F. H. Hamilton, D. Chamberlain, Elias Marsh, J. G. Johnson, Joseph Halderson and J. G. Allan.

SCIENTIFIC INTELLIGENCE.

I. Physics and Chemistry.

1. *Lunar Disturbance of Gravity.*—Mr. G. H. Darwin and Mr. H. Darwin working upon a suggestion of Sir W. Thomson have been investigating experimentally the lunar disturbance of gravity and the question of the tidal yielding of the solid earth. The apparatus which they used was, in its main features, due to Sir W. Thomson and consisted of a solid lead cylinder, weighing a pound or two, which was suspended by a fine brass wire about five feet in length from the center of the cross beams of a solid stone gallows. A spike projected a little from the bottom of the cylindrical weight; a single silk fiber, several inches in length was cemented to this spike, and the other end of the fiber was cemented to the edge of an ordinary galvanometer mirror. A second silk fiber, of equal length, was cemented to the edge of the mirror, at a point near to the attachment of the former fiber. The other end of this second fiber was then attached to a support, which was connected with the base of the stone gallows. A small displacement of the pendulum in a direction perpendicular to the two silks caused the mirror to turn about a vertical axis. A beam of light was reflected from the mirror and received upon a scale. The movements of the mirror were found to be very irregular and several modifications were made in the apparatus. The pendulum was hung in fluid by two wires, and was free to oscillate only in one direction, and a suitable appliance was added by means of which the values of the deflections were obtained. It was found "that the pendulum was subject to a diurnal oscillation, and that it stood farthest north toward 6 P. M. and farthest south toward 6 A. M. Superposed on this was a gradual change of the mean diurnal position, for during two months the pendulum moved northward." The apparatus was extremely sensitive. "Water poured on the ground, at the basement of the stone gallows, tilted the whole structure, and small changes of temperature were found to give distinct effects; 1 foot of displacement in the spot of light on the scale corresponded to 1″ of change in the direction of the plumb line with reference to the base of the gallows." The suspension of the apparatus proved, however, to be unsatisfactory and further modifications were made with the improved apparatus; similar diurnal oscillations of the pendulum were again observed, and a similar slow change in the mean diurnal position, and the authors conclude that these changes indicate a real phenomenon and do not depend upon the errors of the instrument. Periods of continued agitation lasting for several days were also noticed. These periods do not seem to be connected with external meteorological conditions. The pendulum was not sensitive to local tremors but it was extraordinarily sensitive to steady forces. When a person

stood in a room sixteen feet from the instrument, and again at seventeen feet, the difference of pressure was distinctly shown by the pendulum. An alteration of the plumb line through $\frac{1}{100}$ of a second of arc was easily measurable. The experiments of the authors confirm the previous results of M. d'Abbadiela and also of M. Plantamour, who found that there were periods of agitation and quiescence of the earth's surface without reference to any perceptible external cause, and that there were gradual changes of level extending over several months, and indications of an annual inequality of level. In short the earth's surface appears to be in a state of continual movement. Previous experiments of Mr. Horace Darwin upon earth movements are also described. The authors suggest that greater precautions should be taken in the protection of piers for transit instruments. They have no hope of being able to observe the lunar attraction in the present site of observation, but think they may be able to devise a portable instrument which could be used at the bottom of a deep mine if a support sufficiently invariable could be found there. (Report of Committee of the British Association, consisting of Mr. G. H. Darwin, Sir W. Thomson, Professor Tait, Professor Grant, Dr. Siemens, Professor Purser, Professor G. Forbes and Mr. Horace Darwin, appointed for the measurement of the Lunar Disturbance of Gravity. Account of experiments by G. H. Darwin and H. Darwin; read at York, September, 1881.)—*Nature*, Nov. 3, 1881. J. T.

2. *On Drops floating on the surface of Water.*—Drops of water are frequently seen floating for some time on the surface of water before they disappear. This phenomenon is frequently seen during showers, and at the prow of a boat which is throwing up spray. The results of experiments by Professor Osborne Reynolds show that the surface of water upon which these drops are maintained must be clean. Owing to the great surface tension of water scum is generally found floating upon it. If flower of sulphur is scattered upon the surface and then removed by suitable means, the scum is carried with the sulphur and the water is left clean. Upon this cleaned surface drops of water float about for some time. These drops are entirely confined to the surface which is clear. The temperature or condition of the air do not appear to affect the phenomena.—*Literary and Phil. Society, Manchester*, Oct. 4, 1881.—*Nature*, Nov. 3, 1881. J. T.

3. *Photometric investigation of the absorption of light.*—C. Pulfrich employed Vierordt's spectro-photometer and also Glans's instrument for this investigation, and gives a number of curves which indicate the relation between what is termed the extinction coefficient and the absorption constants of the substances examined. The variations of these relations under different conditions are discussed; and Ketteler's formula which expresses the relation between refraction coefficients, extinction coefficients and wave lengths is examined experimentally.—*Annalen der Physik und Chemie*, No. 10, 1881, p. 177. J. T.

4. *Density of the Earth.*—Ph. v. Jolly has employed the balance to directly determine the density of the earth. A body was weighed in two stations distant 21·005^{m} vertically from each other. The errors incident to this method were examined and the value obtained for the earth's density was $\rho=5{\cdot}692$. The results obtained by previous observers are as follows:

Maskelyne	4·713
Cavendish	5·48
Reich	5·58
F. Baily	5·66
A. Cornu and J. B. Baille	5·56
Carlini	4·837
Airy	5·480

—*Annalen der Physik und Chemie*, No. 10, 1881, p. 331. J. T.

5. *On a new arrangement for sensitive flames;* by Lord Rayleigh.—A jet of coal gas from a pin-hole burner rises vertically in the interior of a cavity from which the air is excluded. It then passes into a brass tube a few inches long, and on reaching the top, burns in the open air. The front wall of the cavity is formed of a flexible membrane of tissue paper, through which external sounds can reach the burner.

The principle is the same as that of Barry's flame described by Tyndall. In both cases the *unignited* part of the jet is the sensitive agent, and the flame is only an indicator. Barry's flame may be made very sensitive to sound, but it is open to the objection of liability to disturbance by the slightest draught. A few years since Mr. Ridout proposed to enclose the jet in a tube air-tight at the bottom, and to ignite it only on arrival at the top of this tube. In this case, however, external vibrations have very imperfect access to the sensitive part of the jet, and when they reach it they are of the wrong quality, having but little motion transverse to the direction of the jet. The arrangement now exhibited combines very satisfactorily sensitiveness to sound, and insensitiveness to wind, and it requires no higher pressure than that of ordinary gas-pipes. If the extreme of sensitiveness be aimed at, the gas pressure must be adjusted until the jet is on the point of flaring without sound.

The apparatus exhibited was made in Prof. Stuart's workshop. An adjustment for directing the jet exactly up the middle of the brass tube is found necessary, and some advantage is gained by contracting the tube somewhat at the place of ignition.—*Cambridge Phil. Soc.*, Nov. 8, 1880.

6. *On an effect of vibrations upon a suspended disc;* by Lord Rayleigh.—In the British Association experiment for determining the unit of electrical resistance, a magnet and mirror are enclosed in a wooden box, attached to the lower end of a tube through which the silk suspension fiber passes. Under these circumstances it is found that the slightest tap with the finger-nail upon the box deflects the mirror to an extraordinary degree. The disturbance appears to be due to aerial vibrations within the box, acting upon the mirror. We know that a flat body, like a mirror, tends to

set itself across the direction of any steady current of the fluid in which it is immersed, and we may fairly suppose that an effect of the same character will follow from an alternating current. At the moment of the tap upon the box the air inside is made to move past the mirror, and probably executes several vibrations. While these vibrations last, the mirror is subject to a twisting force tending to set it at right angles to the direction of the vibration. The whole action being over in a time very small compared with that of the free vibrations of the magnet and mirror, the observed effect is as if an impulse had been given to the suspended parts.

The experiment shown is intended to illustrate this effect. A small disc of paper, about the size of a sixpence, is hung by a fine silk fiber across the mouth of a resonator of pitch 128. When a sound of this pitch is excited, there is a powerful rush of air in and out of the resonator, and the disc sets itself promptly across the passage. A fork of pitch 128 may be held near the resonator, but it is better to use a second resonator at a little distance in order to avoid any possible disturbance due to the neighborhood of the vibrating prongs.—*Cambridge Phil. Soc.*, Nov. 8, 1880.

7. *Edison's Electrical Meters.*—A recent number (Nov. 23), of the excellent electrical Journal "La Lumière Électrique," contains a description by the scientific editor, M. Th. Du Moncel, of two forms of meters designed by Mr. Edison to measure the amount of electricity consumed in a given case either for mechanical purposes or for lighting. One of these is very simple in construction, but requires that a weighing operation should be performed each time it is desired to learn the amount of electricity which has been consumed; the other is somewhat more complicated, but accomplishes all its results automatically, making a record on a dial after the manner of ordinary gas meters.

The first of these consists of two closed copper sulphate voltameters placed in separate adjoining compartments of the enclosing case; to one of these the subscriber is supposed to have access and the other is to be used for verification by the officer of the company which supplies the electricity. The electrodes in each cell are formed of copper plates placed near to each other so that as the current passes a deposit of copper is made on one of them by the electrolytic action. The current passing through the voltameters is a branch of the main current which is being used, and by means of a small resistance coil its intensity is reduced to a small fraction, perhaps one one-hundredth, of it. The use of the instrument is as follows: When the current passes in the main circuit to effect its work, either mechanically or in illumination, a certain known portion of it traverses the two voltameters and causes in them a deposit of copper which is proportional to the given current in the given time. As the exact relation between the intensity of the current which traverses the voltameters to the main current is known, it is easy to deduce the quantity of electricity which has been used from the amount of copper deposited on the negative electrode; the weight of copper

is obtained whenever desired by removing the electrode and weighing it. As a supplementary arrangement, designed to remove all danger of the freezing of the liquid in the voltameter, a metallic thermometer is placed beneath, so adjusted that when the temperature falls near the freezing point a second branch current is sent through an incandescent lamp and the heat thus produced is sufficient to accomplish the end named.

The second form of electrical meter cannot be intelligibly described in all its ingenious details without reference to the figure which accompanies the original article, but the main principle is not complex. It consists of two voltameters each placed beneath one end of the beam of a balance. The cells are filled with saturated copper sulphate and in each there is a fixed cylindrical electrode of copper and fitting within it a similar electrode but movable, being suspended from the beam of the balance above. The arrangement of the current is such that these electrodes play alternately the parts of electrodes of solution and of reduction. As the current passes there results, consequently, first an increase of weight of one movable electrode from the deposit of copper, and a loss of weight of the other, and this causes a deflection of the beam of the balance. A counterpoise suspended by a slender vertical rod, from the center of the moving beam, is thus moved to one side until contact is made with an electro-magnet, and by means of an oscillating lever the current is reversed. In consequence of this change the respective gain and loss of weight of the movable electrodes are also reversed, and corresponding to this the balance beam regains its horizontal position and is then deflected to the other side. This continues until, as before, the movement of the counterpoise causes another reversal of the current, and so on. By means of the same oscillating lever which, by its connection with the suspended counterpoise, brings about the reversal in the current at the proper moment, each deflection of the balance beam is registered on a dial plate, and as the relation between the current in use and that passing through the voltameters is exactly known, and as the weight of copper which must be deposited on the movable electrode in order to bring about one swing of the balance (determined by the weight of the counterpoise) is also known, it is easy to deduce the amount of electricity which has been used from the readings of the dial plate.

8. *On the Carbonic acid in Sea-water;* by HERCULES TORNÖE. (The Norwegian North Atlantic Expedition of 1876–1878. Chemistry, pp. 24–44).—The early determinations of the amount of carbonic acid in sea-water show a very wide variation. For example, Frémy gives 2·2 to 2·8 c. c. to the liter of surface water; Pisani gives 6·0 to 8·1 c. c.; while by a somewhat different process Bischof obtained 39·0 c. c. and Vogel 55·6 to 116·3 c. c. In these earlier experiments the carbonic acid was driven off by boiling under the normal pressure, and the amount thus collected was assumed to have been present free as gas or, to a small extent, combined in bicarbonates. In the later determinations,

made in connection with the "Pommerania" Expedition of 1871, in which the gaseous elements in the water were boiled out at a very low temperature under diminished pressure, it was found that the quantity of carbonic acid expelled was small; moreover, when the same sample of water was again boiled the results obtained were very variable. Jacobsen was led by these results to investigate anew the absorptive capacity of sea-water for carbonic acid. He determined the amount contained in the water of the North Sea to be about 100 mgr. per liter, and of this he concluded that only a very small proportion was obtained from the bicarbonates; and further he was confident that no portion of the neutral carbonates was decomposed by the boiling process. He found, however, that even when the boiling process was carried on under the full atmospheric pressure the carbonic acid, though supposed to exist in the gaseous form, escaped so slowly that concentration to about one-tenth of the original volume was needed to obtain it all. To account for this phenomenon Jacobsen ascribed to sea-water a peculiar power of retaining its carbonic acid depending, as he believed, upon the magnesium chloride present. This hypothesis was adopted by J. Y. Buchanan, chemist of the "Challenger" Expedition, who also, as the result of a series of experiments, concluded further that most of the salts present in sea-water had this property of retaining the carbonic acid, but most of all the sulphates. He, accordingly, in his determinations first precipitated the sulphuric acid by barium chloride, but otherwise adopted the method of Jacobsen. The amount of carbonic acid in the water of the Southern Seas he found to be 43·26 mgr. per liter.

The conclusions which have been described were, however, questioned by Tornöe, of the Norwegian North Atlantic Expedition, and his experiments lead to a very different result. Considering it more probable that the carbonic acid obtained was derived from the decomposition by the protracted process of boiling of the neutral carbonates present, than that it existed as a gas and was retained under the peculiar conditions supposed, he carried on a series of experiments to decide this point. Two hundred c. c. of sea-water were distilled nearly to dryness and the carbonic acid collected in baryta water; 20·2 mgr. were found to have been driven off. Freshly boiled water was now poured on the residue and it then evaporated, the result yielding only a trace of carbonic acid; finally some purified and freshly-heated soda was added, and the whole again diluted to the original volume. As soon now as the boiling commenced, the carbonic acid was liberated in quantities so large that part passed unabsorbed through the baryta water. The experiment was also repeated with precipitated calcium carbonate, and the carbonic acid expelled from it in considerable quantities, though not so large as before. These results prove beyond question that the earlier methods of determining the free carbonic acid in sea-water were inaccurate, inasmuch as the boiling process causes a decomposition of the neutral

carbonates. In the autumn of 1878 the experiments of Tornöe were again resumed, after an interval of about a year. By the use of an improved form of apparatus devised by Classen, the total amount of carbonic acid yielded by sea-water on boiling was determined, and found to agree very closely with that obtained by Jacobsen's method. The determinations were, however, carried still further, and not only the total amount measured but also that portion present in combination with neutral carbonates, and the difference between the two gave the amount combined with bicarbonates, for it is shown that the earlier observations can only be explained in case the water contains no free gas. Tornöe gives a table in which the results of seventy-eight determinations, made with water taken between 65° and 80° N. latitude, from various depths, from the surface down to 1861 fathoms. The table shows a remarkable constancy in results, the amount of carbonic acid forming carbonates varying from 48·4 to 54·7 mgr. per liter, and that forming bicarbonates from 39·7 to 48 mgr. If a few exceptional observations made on water taken from points near the ice on the coast of Greenland are excluded, the extreme variations are only 4 mgr. and 8 mgr. respectively. As the average result, the amount of carbonic acid forming neutral carbonates is found to be

$$52{\cdot}78 \pm 0{\cdot}083 \text{ mgr.}$$

per liter, with a probable error for a single observation of 0·662 mgr., and for that forming bicarbonates

$$43{\cdot}64 \pm 0{\cdot}16 \text{ mgr.}$$

with a probable error of 1·26 mgrs. per liter. A series of experiments were also carried on to explain the liberation of gas from the carbonates on boiling, and the conclusion is reached that this is due to the slow reciprocal action of the carbonates and salts of magnesia it contains. In regard to the character of the carbonates present in sea-water, Tornöe believes it probable that they are rather sodium and potassium carbonates than carbonate of calcium, this supposition serving to explain the alkaline reaction of sea-water noted by him, and also the resistance to decomposition observed, allowing of their being exposed for an hour together to a temperature of nearly 90° C. without effect. Earlier determinations of the amount of carbonates present have given in some cases none, in others only traces, and in others as much as 0·3 gr. per liter. This variation is explained by the fact, which will be clear from what has preceded, that the methods employed were not such as to allow of even approximate accuracy.

9. *On the Action of the Oxides of Nitrogen on Glass at a high temperature;* by Thos. M. Morgan.—Several attempts were made to determine the nitrogen in organic nitro-derivatives by heating the substance in sealed tubes of hard glass containing oxygen, and in presence also of a little mercury to effect the reduction of any oxides of nitrogen which might be formed, but in all cases the nitrogen obtained was considerably less than the

quantity theoretically present in the substance analysed. The source of this deficiency was eventually traced to the action which the oxides of nitrogen exerted on the alkali of the glass, and also on the mercury. For when some of the tubes which had been subjected to a temperature not above dull redness were washed with a little water, the washings could always be shown to contain a nitrate and a soluble salt of mercury; others, the temperature of which had been higher, contained nitrates and nitrites, but no soluble mercury salt.

For the purpose of showing more conclusively that the glass was thus attacked, and in order also to investigate the extent of the action, the following experiment was performed: A tube of hard glass, 50 c. c. capacity, was cleaned until the evaporated washings left no appreciable residue. A quantity of oxygen was next introduced, and then so much nitric oxide that the tube was filled with red fumes; after which it was heated to dull redness for two hours. When cold it was still full of red fumes, and when these were withdrawn it was washed as before, and the evaporated washings left a residue of 0·0038 of a grm., consisting of nitrates and nitrites The same experiment was repeated three times on the same tube; the second residue was 0·0044 of a grm., and the third 0·0022. Another tube gave 0·0048.

As might be expected, this action is much more energetic at a high than at a low temperature, and it appears to be very slight until the heat approaches redness. In the analysis of such nitrogenous compounds as have the nitrogen in combination with oxygen, a certain deficiency of nitrogen, varying with the temperature employed, may therefore be expected.—*Chem. News*, *Nov.* 25, 1881.

II. Geology and Mineralogy.

1. *On the Periodical Variations of Glaciers.*—Mr. F. A. Forel, of Morges, has an important memoir on this subject in the Geneva Archives des Sciences Physiques et Naturelles, July, 1881, based on observations in the Alps. He refers to the great elongation of the Grindelwald glacier in 1593, that of the Bossons in 1817, of the Gorner glacier in 1857, and also of the remarkable shortening of the Grindelwald glacier in 1540 and of the large Swiss glaciers generally in recent times, and seeks to ascertain the cause of the changes. The following is a brief review of his argument.

The length of a glacier varies, beyond doubt, with (1) the supply of snows, and (2) the melting of the ice or *ablation* by means of heat. Abundant snows lengthen it; heat thins and shortens it. The shortening by heat in summers, or the supplies of snow in the winters immediately preceding, have been referred to as the chief cause of variation. But observations show that glaciers lengthen during cold summers, when the snows are not sufficient to account for the change. The true theory was sug-

gested in 1821 by Venetz, and fully propounded in 1831 by F. J. Hugi, the able professor of Soleur. The points are these:—

(1.) *The law of long periodicity.* — Glaciers vary by long periods—five, ten, twenty years or more, not by annual changes. The Pfarrbuch of Grindelwald, from 1575 to 1602, underwent great elongation; from 1602 to 1620, was stationary; from 1665 to 1680, shortened; in 1703, reached its maximum elongation; in 1720, reached a maximum retreat, and in 1743, a maximum elongation; in 1748, again made a maximum retreat; in 1770 to 1778, lengthened; in 1819, became much elongated, and in 1840 was still advancing; but from 1855 to 1880, has had a period of retreat.

(2.) *The law of variation contained in the law of retreat.*—In 1870 and 1871, Dufour and Forel, when studying the condensation of the moisture of the air on the glacier of the Rhone and the evaporation of the ice, were struck with the fact of the very evident retreat of this great glacier. From observed facts by Ph. Gosset and his aids, of the Swiss Alpine Club, it has been found that from 1857 to 1870 the retreat was 23 meters a year; from 1870 to 1874 the retreat was 71 meters a year; and from 1874 to 1880 the retreat was 41 meters a year. Thus, through 24 years, retreat has been going on with no year of advance. So, also, the glacier des Bois was in retreat from 1854 to 1875; that of the Bossons from 1854 to 1875, and the upper glaciers of Grindelwald have continued to retreat since 1855.

The facts connected with the Rhone sustain the conclusion that—

The determining factor in the variations of length in glaciers is not ablation, but the rate of onward movement in the ice.—The flow of the ice-stream acts conjointly with the melting. The latter is a consequence of annual changes and therefore is irregular and of rapid action, and hence cannot be the cause of the long periodicity exemplified in the glacier of the Rhone. The former depends on changes of long periodicity in meteorological conditions—heat, moisture, winds.

In the 24 years, from 1857 to 1880, there were 15 years in which the mean temperature of the summer was above the normal, and 9 years in which it was below; 16 years in which the mean for the year was above the average, and 8 in which below; and these numbers were for the absolute humidity, 14, 10, and 16, 8; and for precipitation, 14, 10, and 12, 12. Thus the long-period condition was one that should have produced a retreat; the diminished flow of the glacier was the great factor and must be so for all cases. Ablation does an important part of the work, but is subordinate to the rate of flow.

Small variations in the thickness of a glacier in its upper part toward its source, produce large changes in the movement below. Augmented thickness above produces more rapid movement, and consequently a less long exposure to ablation, and thereby less loss in ice; and the reverse for diminished thickness. The gla-

cier when shortening, loses also in its other dimensions. There is internal ablation as well as external—interstitial fusion taking place between the grains of the glacier and ablation along the walls of crevasses; and this action, besides being one of the means by which the thinning takes places, causes loss of movement, the amount of which diminishes upward along the glacier. Moreover, the greater the thickness the less proportionally is there of this internal ablation. Internal ablation tends then to exaggerate the small variations in the rate of flow, and produces great effects in the inferior part of the glacier, although small above.

The variations in the amount of snows, which cause the greater thickness of the glacier at its source, depend on long terms of periodicity. The precipitation at Geneva was below the normal (88159^{mm}) from 1835 to 1841 inclusive; above it, 1842 to 1857; near the normal in 1858 to 1861; below it in 1862 to 1877; above since 1877. It is seen that there is an approximate parallelism between these changes and the variations in the glaciers of the Alps. The effects are not immediate, as should be expected, but follow more or less closely the greater meteorological movements.

It is seldom that all the glaciers of the Alps, without any exception, lengthen or shorten together. In this century, the only case of simultaneous elongation took place in the year 1817 and 1818, and the only one of general retreat in 1872 to 1874. During the years 1812 to 1836, most of the glaciers underwent a shortening; but the Bois, Unteraar, and Gorner glaciers continued for some years their movement of elongation. The period of shortening which included the above-mentioned years, 1872–1874, commenced in Mont Blanc about 1854; in the Upper Grindelwald, in 1855; the Giétroz, in 1855; the Rhone, in 1857; the Aletsch, in 1860; the Gorner, in 1870; the Fiesch, in 1870; the Unteraar, in 1871; and it ended with the Bossons about 1875; with the Bois, in 1879; the Trient, in 1879; the Giétroz, in 1880. The facts seem to show that it took twenty years after the cycle of retreat began for the time of *simultaneous* retreat to arrive.

Hugi, besides giving the above explanations, illustrates them by reference to the same class of facts, though of less range of years.

With regard to the coming on of the conditions of the Glacial period in the Alps, the author attributes the result chiefly to a gradual, but feeble, augmentation in the annual fall of snow depending on slight changes in hygrometric conditions, connected with a series of moist and mild winters and moist and cold summers, as was long since suggested by Professor Guyot. The increase in the snows thickens the ice, quickens movement, widens the area of the névé, unites glaciers before separate and thus quickens the rate of flow through a diminution of friction; causes an increase of snows and a general cooling of the climate; makes new glacier areas, and tends thus to augment all the above-mentioned effects.

But M. Forel adds, while these effects would follow in mountain regions like the Alps, other regions, as the Vosges, the Cé-

vennes, the mountains of Scotland, etc., which are now remarkable for the amount of rain, show that increase in humidity is not the only cause needed to bring on a Glacial era; it is necessary also for such countries that there should have been a general lowering of the temperature of Europe.

2. *On the Movement of Glaciers.*—The observations made by Messrs. Koch and Klocke in 1879, on the Morteratsch glacier in Eastern Switzerland to determine the rate and character of its movement have already been described in this Journal (xix, 425). The same observers in the following year (Sept., 1880) made a second series of similar measurements, using essentially the same methods as before. It will be remembered that their first observations seemed to prove a considerable and unexpected degree of irregularity in the movement. It was found, for example, that the same point could have a motion in both a vertical and horizontal direction, and that two points not very far apart, in some cases, moved at a different rate or even in opposite directions. The observations of 1880 have, on the whole, given a rather negative result since, for some unknown reason, the motions measured were much smaller than before, those in a vertical direction, for example, hardly exceeding the unavoidable errors of observations. The authors state in detail their improved methods and the means taken to eliminate the errors, and finally give tables showing the results of their measurements during two or three days out of the fourteen over which the series extended. They conclude that the amount of observed movement, vertical and horizontal, often did not exceed the probable error, and hence their results do not allow of satisfactory discussion, but that they, notwithstanding, indicate real ice movements, and are not to be referred to irregularities in the position of the observing telescope.— *Wied. Ann.*, 1881.

3. *On Soilcap-Motion;* by R. W. Coppinger, Esq., M. D.— I wish to call attention briefly to a phenomenon which, so far as I am aware, exists to an unparalleled degree about the shores of Western Patagonia, and whose presence there is in a great measure due to the exceptionally wet nature of the climate. I allude to a slippage of the soilcap, which is, I believe, continually taking place over the basement rock wherever the latter presents a moderately inclined surface. Some of the effects of this soilcap-motion are apt to be confounded with those due to glacial action; for the soilcap takes with it in its progress not only its clothing of trees, ferns, and mosses, but also a "moraine profonde" of rocks, stones, stems of dead trees, peat and mud, whereby the hills of this region are being denuded, and the valleys, lakes and channels, gradually filled up.

On arriving at the Patagonian archipelago my attention was directed to this subject on noticing that the lower branches of trees fringing the sea-shore were in many places withering from immersion in the salt water, and that in some cases entire trees had perished prematurely from their roots becoming entirely sub-

merged. On looking more closely I observed that the sodden snags of dead timber, mingled with stones, were often to be seen at the bottom of the inshore waters, and that the beds of fresh-water lakes were plentifully strewn with similar fragments of wood, the remains of forests prematurely destroyed. As the soilcap, by its sliding motion, reaches the water, the soluble portions are removed; and just as stones and bowlders are often seen deposited in grotesque situations by a melting iceberg or a receding glacier, so are the phenomena of "perched rocks" to be here observed, although, in the class of cases to which I refer, due to a totally different cause. These facts are all the more interesting from their occurring in a region where the effects of *old* glacial action are to be seen in a marked degree. Planings, scorings, striæ and "roches moutonnées" may almost invariably be found wherever the rock is sufficiently capable of resisting the disintegrating influence of the weather to retain these impressions. Thus they are nowhere to be seen on the coarse-grained, friable syenite, which is the common rock-formation of the district; but where this rock is intersected by dikes of the more durable greenstone, the above-mentioned signs of former glacial action may be seen well developed. There are therefore in this region ample opportunities of comparing and differentiating phenomena which have resulted from "glacial action" and those which are due to "soil-cap-motion"—a force now in active operation.

I may here observe that we did not see any glaciers worthy of the name either on the western islands or abutting on the mainland shores of Patagonian channels, although they undoubtedly exist farther eastward, and discharge icebergs at the head of some of the deep fiords. In the main straits of Magellan there are fine examples of complete and incomplete glaciers, where may be observed, in all its grandeur, the wonderful denuding power which these ponderous masses of ice exercise as they move silently along their rocky beds.

Sir Wyville Thomson (vide 'Voyage of the Challenger,' the "Atlantic," vol. ii, p. 245) attributes the celebrated "stone rivers" of the Falkland Islands to the transporting action of the soilcap, which, among other causes, derives its motion from expansion and contraction of the spongy mass, due to varying conditions of moisture and comparative dryness; and this hypothesis is to a certain extent supported by the occurrences which I am now endeavoring to describe. Here, in Western Patagonia, are evergreen forests, and a dense undergrowth of brushwood and mosses clothes the hillsides to a height of about 1000 feet; and this mass of vegetation, with its subjacent soil, resting as it frequently does upon a hillside already planed by ice-action, naturally tends, under the influence of gravitation, combined with that of expansion and contraction, to slide gradually downward until it meets the sea or a lake or valley. In the first two cases its free edge is then removed by the action of the water, in a manner somewhat analogous to the wasting of the submerged snout of a Greenland glacier in the summer time; and in the last case the valley becomes converted into a deep morass.

It appears to me that the conditions which are said to have resulted in the production of the "stone rivers" of the Falklands here exist in equal if not greater force. There is the thick, spongy, vegetable mass covering the hillsides and acted on by varying conditions of extreme moisture and comparative dryness; there are the loose blocks of disintegrating syenite to be transported; and there are the mountain-torrents, lakes and sea-channels to remove the soil. Of actual motion of the soilcap we have at least strong presumptive evidence; but nowhere in the valleys have I found anything resembling a "stone river."

It might perhaps be thought that a slow and gradual depression of the land would account for some of the above phenomena; but I have seen no reliable sign whatever of *subsidence*, and have, on the contrary, the evidence of numerous raised beaches and the work of the stone-boring mollusca at heights above the present sea-level to prove that *elevation* of the land has taken place.

The subject is one full of interest; and feeling confident that it will repay further investigation.—*Quart. J. Geol. Soc.*, 1881, 348.

4. *Evaporation and eccentricity as co-factors in Glacial periods.* —Rev. E. Hill discusses this subject in a paper published in the Geological Magazine, viii, p. 481, November, 1881. He observes that the capacity of air for aqueous vapor increases with the temperature, but in a rapidly increasing ratio; and accordingly the absolute quantity of vapor required to saturate a given volume of air at different temperatures varies much more widely than do the temperatures. A consequence of this relation is, that if two volumes of saturated air of different temperatures are mingled, precipitation must occur. For example, a cubic meter of air at 10° C. and 20° C. would contain, respectively, 9·83 and 17·19 grams, or an aggregate of 26·57 grams of vapor; but when mingled, the mixture would assume the mean temperature of 15° C., and could then contain but 25·54 grams of vapor. Conversely, the capacity for vapor of two cubic meters of dry air at different temperatures is greater than that of a similar aggregate volume at the mean of these temperatures. Hence, since the rate of evaporation is dependent on the capacity for vapor of the air above the water, it follows that *the mean evaporation under varying temperatures exceeds the evaporation at the mean temperature;* and, moreover, *when temperatures vary about a mean, increased variation produces increased evaporation.* A high degree of eccentricity in the terrestrial orbit increases the annual range in temperature, and accordingly augments the total evaporation, and hence, also, the precipitation; and since the heat absorbed in evaporation is taken from the earth's surface, while that given out in condensation is lost high in the atmosphere, it is manifest that the total loss of heat by the earth must be increased.

These considerations support Croll's view of the relation between high eccentricity and glacial periods. Though this effect of evaporation is here clearly recognized for the first time, it is among the agencies whose combined influence was

empirically computed by the writer in the December number of this Journal. W. J. MCGEE.

5. *Report on the Geological and Natural History Survey of Minnesota for* 1880; N. H. WINCHELL, State Geologist. 392 pp. 8vo, with vi plates. St. Peter, 1881.—This new volume contains detailed Reports on the Forestry of Minnesota by O. E. GARRISON; on the geography and hydrology of the Upper Mississippi by C. M. TERRY; and on the Glacial phenomena of the State and the region some distance north and west by WARREN UPHAM; also a descriptive list of rocks, descriptions of three new Lower Silurian Brachiopods (two of Orthis and one of Strophomena), and a note on the Cupriferous series by Prof. WINCHELL; a list of the birds of Minnesota by Dr. P. L. HATCH; and a note on an ancient outlet of Lake Manitoba by H. S. TREHERNE.

The report on the hydrology treats of the rivers and lakes and other features with much detail. It states among its facts, that the lakes, of which there are several thousand, are gradually diminishing in extent and depth, or drying up, and attributes the change that is going on chiefly to cultivation. The rain waters which formerly made streamlets over the grassy prairie, and thus reached the lakes, now fall on ploughed soil and are absorbed. The records at Fort Snelling since 1836 show as yet no evidence of change in amount of rain. The profuse growth of water plants also tends to fill them. They often have low ridges of gravel and stones along the shore, which were made by the pushing action of ice when freezing, and also by transportation shoreward when the lakes are flooded. An excellent map (Pl. V) illustrates this report.

Mr. Upham's account of Glacial phenomena is devoted largely to the courses of terminal moraines and is full of interest. The facts are presented also on a map, on which the courses of the moraines, and the supposed direction of movement of the glacier are laid down. The courses of Glacial striæ in different parts of the State are given in a table as well as on the map, and indicate wide variations, the limits being S. 60° E. and S. 60° W. The map represents the outline of the moraine as extending from the Mississippi, between the meridians of 93° and 94°, south to the parallel of 41½°, and then as trending northwestward with some westing to the Coteau des Prairies whose course it follows. West of this range, according to information derived from different sources, the moraine bends southward in latitude 45½° and continuing to latitude 43° (or nearly to the Missouri) between the meridians of 97° and 98° making a second prolongation or lobe which has the Coteau du Missouri along its western side. The drift sheet is stated to be 100 to 200 feet thick over the western two-thirds of Minnesota —and the material is for the most part an unstratified mixture of earth, stones and clay. The color below is usually dark bluish.

The drift contains stones of Archæan rocks from north of Lake Superior, occasional masses of native copper from the vicinity of the same lake, and limestone bowlders probably from Manitoba; and some of the Archæan in the till south and west of Minnesota

were probably transported 500 to 700 miles. The following general statement of Mr. Upham's conclusion is from an early page of his report:

"The terminal moraines, which form the principal subject of this report, show that the southern portion of the continental ice-sheet was divided into great lobes, each having a central current in the direction of its longer axis, with diverging currents bending from this and becoming perpendicular to its border. The red and blue till were the deposits of two such ice-lobes which overspread Minnesota from the northeast and northwest. During the most severe epoch of the ice age, before that in which the terminal moraines of Minnesota were accumulated, an ice-sheet reached much farther south, to a limit 20 to 100 miles southwest and south of the Missouri river and within a less distance north of the Ohio river. Portions of this glacial sheet, moving from the northeast, north, and northwest, enclosed an area about 150 miles long from north to south and 100 miles wide, lying principally in southwestern Wisconsin, but extending into Illinois, Iowa and southeastern Minnesota, which was not covered by ice and has no till nor striæ. This driftless area has a less average height than the adjoining regions which were glaciated. Climatic conditions of greater snow-fall and lower temperature seem to have produced the ice-fields, which lay at each side of this tract and were confluent farther south. The wedge-shaped area of highland that reaches southwest from Keweenaw Point, at the south side of Lake Superior, and the depressions of Lake Michigan and Lake Superior, have also been regarded as the causes of this division of the continental glacier.

The occurrence of this driftless tract shows that the ice-sheet which reached farthest south was divided in portions that moved independently, with diverging and converging currents; and that in respect to the districts over which they extended, these glacial movements corresponded to the lobes that formed the southern part of the ice-sheet at the later time when the looped moraines of Wisconsin, Minnesota, Iowa and Dakota were pushed out at its margin."

6. *On joints or diaclases intersecting the stratified rocks in the vicinity of Paris;* by M. Daubrée, (Bull. Soc. Géol. de France, June, 1880).—This very interesting paper contains details as to the two directions of joints or fractures, nearly at right angles with one another, which exist at the various quarries in Tertiary and Cretaceous strata about Paris. M. Daubrée points out the system in their courses, and the exceptional directions, and also their general parallelism to the reliefs of the region (the most prominent being parallel to the outcrops of the Chalk and the valley of the Seine) illustrating the same by a map; and he remarks on the perfect conformity to the results of his experiments making fractures, by pressure and torsion described in his great work on Experimental Geology.*

* See also, for a notice of these experiments, Dana's Manual of Geology, edition of 1880, pages 801, 832.

7. *Brick-clays making cream-colored bricks in Minnesota.*—Professor N. H. WINCHELL, in Miscellaneous Publications, No. 8 of the Geological Survey of Minnesota, states that the clays of many localities in Minnesota (among them Brainerd, Minneapolis, Carver, Chaska and Jordan), afford on burning cream-colored brick, and a few, brick of a dirty drab or ash-gray. The clay is described as an *alkaline* clay, and like the related clay of Milwaukee, partially fuses therefore in the baking, so that the iron present (which may be as much as in other clays) enters into combination with the silica and alumina instead of remaining as oxide, a point first explained by Mr. E. T. Sweet. These alkaline clays are those of the earlier drift, and are supposed by Professor Winchell to have been derived from the clay-beds of the Cretaceous. The clay-beds in the State connected with the later alluvium make red brick.

8. *Geology of Frenchman's Bay, Maine, just east of Mount Desert Island.*—This locality is the subject of a paper by W. O. CROSBY in the Proceedings of the Boston Society of Natural History, 1880, p. 109. The schistose rocks of the region about Frenchman's Bay are an obscurely crystalline mica schist, quartzite, siliceous argillite, sometimes hornblendic; and the group is metalliferous, it containing the silver-bearing vein at Sullivan Falls. These rocks are stated to occur on the north side of Frenchman's Bay and to be part of an extensive formation bordering the coast at intervals from the Penobscot to New Brunswick. On the islands of the bay are other rocks, referred to a later age, which are entirely uncrystalline, the chief kind being a slate of black, drab and purplish shades of color, passing into siliceous slate and sandstone and a micaceous slate. They contain no fossils in Frenchman's Bay, but the same slate on the southwest side of Hawthorne Island, afforded Mr. Crosby markings resembling the *Palæochorda minima* of Emmons; and a similar slate has afforded at Narraguagus, according to Professor E. S. Hitchcock, an *Orthis* and *Crinoidal joints*, and at Foster's Island off Machiasport, undetermined *Rhynchonellæ*. Mr. Crosby agrees with Professor Hitchcock in referring the slate rocks of Frenchman's Bay, probably to the Cambrian or Primordial. The rocks of the region are intersected by dikes of diorite or allied rocks and granite.

9. *Coking coal and anthracite of Colorado.*—Professor J. S. NEWBERRY, in the Transactions of the New York Academy of Sciences, for 1881–1882, p. 8, observes that a coking coal occurs within twenty-five miles of Crested Butte of special excellence, it being firm, not affected by the weather, and containing but little ash and sulphur. The region borders on a volcanic area, and the coal is from the part of the basin which has mostly escaped alteration by volcanic heat. He remarks also that the anthracite, of Anthracite Creek, according to a recent analysis made at the School of Mines, New York, contains less than one per cent of sulphur, and only three of ash and is not inferior to Pennsylvania anthracite.

10. *Copper-bearing region in Northern Texas and the Indian Territory.*—The geology of this region is briefly described by J. H. FURMAN, in the Trans. N. Y. Acad. Sci. for 1881–1882 (p. 16). The copper ore occurs in shale overlaid by gypsiferous sandstone, the western part of Haskell County, Texas, and is found as nuggets of copper ore, stains of malachite, and wood fossilized more or less completely with copper ore. The strata are about horizontal. The ore was found along a band usually less than fifty yards wide, stretching eight to ten miles, to the southern boundary of the county; also five miles farther north, and in Knox and Hardeman Counties, and beyond in the Indian Territory. Professor Newberry added, in the discussion which followed the reading of Mr. Furman's paper, remarks on the similarity of the ores and their mode of occurrence to the same in the upper portion of the Triassic in New Mexico, and southern Utah, and observes that in the localities hitherto explored, the ore is too much scattered to be profitably mined. The wood, impregnated with the ore and also that which occurred silicified, he said was undoubtedly Coniferous of the Araucarian family, as he had found from a microscopic examination.

11. *The Amygdaloid of Brighton, Massachusetts*, has been examined microscopically by Dr. E. R. Benton, and pronounced to be a true eruptive rock. A paper on the subject, accompanied by a map, is contained in the Proceedings of the Boston Society of Natural History, vol. xx, 416, 1880.

12. *Primordial Trilobites in Sardinia.*—Prof. Meneghini has announced the discovery of new species of trilobites in slaty and arenaceous beds at Gutturu Sergiu in Nebida, Sardinia, which he names *Paradoxides Gennari* (near *P. Bohemicus* in size), *P. armatus*, *P. Bornemanni*, and *Conocephalites Bornemanni.*—*Atti Accad. d. Lincei*, 1881, p. 306.

13. *Journal of the Cincinnati Society of Natural History*, Vol. IV, No. 1.—Contains descriptions of new Crinoids and other fossils of the Hudson River group, and notice of *Strotocrinus Bloomfieldensis* by S. A. Miller (with a plate); descriptions of new fossils of the Lower Silurian and Subcarboniferous rocks of Ohio and Kentucky by A. G. Wetherby (with a plate); on new species of Entomostraca by V. T. Chambers.

14. *Fossils of the Cincinnati Rocks.*—The "Paleontologist" of Cincinnati, edited by U. P. James, contains a notice of *Scolithus linearis* from the Cincinnati group, in the eastern part of Cincinnati; of three species of *Monticulipora* supposed to be new; of *Dekaya maculata* James; of eight species of *Ptilodictya;* and of an *Orthis* and two species of *Streptorhynchus.*

15. *Volcanoes: what they are and what they teach;* by JOHN W. JUDD, F.R.S. (Kegan Paul and Co.: London, 1881.)—This work forms volume XXXV of the International Scientific Series. In his earlier studies the author enjoyed the counsel and assistance of Mr. Poulet Scrope, who up to his death was an eminent authority on volcanoes, and the present book may in some sense be regarded as continuing the work of that pioneer in Vulcanology.

In Chapter I the nature of the inquiry in hand is stated and reference made to the older investigators, Spallanzani, Dolomieu and Scrope. Chapter II deals with the nature of volcanic action, illustrated by the ordinary phenomena of Stromboli and by the eruption of Vesuvius in 1872, and in each case the action is attributed to the elastic force of confined steam. Chapter III describes the characteristics, chemical, mineralogical, and microscopical, of the lavas, while Chapter IV discusses the other ejected materials, scoria, pumice, etc., as also the change of form in volcanoes resulting from ejections of lava and scoria, illustrating by Monte Neuvo, and by the history of changes in the cone of Vesuvius itself.

In Chapter V the internal structure is described, as shown in the Kammerbühl in Bohemia, in Vulcanello and in the volcanic wrecks of the islands of Mull and Skye. In this connection the method of formation of a cone from scoria is experimentally illustrated by the mode of deposition of saw-dust blown vertically from an orifice in a horizontal plane; and the formation from viscid lava, by soft plaster forced through a similar opening, as devised by Dr. E. Reyer. In Chapter VI the author discusses the structures built up about the vents, the cones of scoria, tufa or lava and their varying forms, the parasitic cones formed by lateral openings along fissures in the sides of the main cone, the change of position of the vent along such fissures, the crater-rings and lakes, mud-volcanoes, etc.

Chapter VII gives the life history of the volcano, detailing the probable order of the phenomena, from the first issue of the steam and gases from the rent in the earth's crust, through the eruption of andesitic and trachytic lavas, to the basaltic or basic lavas, the building of the cone, the intrusion of lavas between the adjacent strata forming laccolites, and across the strata forming dikes, the appearance at first of the acid gases at high temperatures, and later when the temperature has fallen, of sulphuretted hydrogen and carbonic acid, and finally of hot water in geysers or springs, until all manifestation of igneous agency disappears and the cycle is complete.

Chapter VIII speaks of the distribution of volcanoes; that of the 300 or 350 active volcanoes, the majority on islands, arranged in lines thousands of miles long, and all near the sea except two or three in Central Asia. And it may be stated here, that advices more recent than the work of which we are writing would indicate that these apparent exceptions in Asia are not really volcanic but are due to beds of coal and petroleum which have become ignited in former years. (See Dr. A. Regel in *Petermann's Mitth.*, vol. xxvii, 10, 1881, p. 384, also General Kolpakofsky, *Nature*, Oct. 27, 1881.)

Chapter IX infers that the volcanic action of earlier geological ages was both in its nature and in its products similar to that of our own day. Chapter X illustrates the part played by volcanoes in the economy of nature, by the growth of the Alpine chain.

Chapter XI discusses the probable condition of the earth's inte-

rior, and Chapter XII the causes of volcanic action, stating at length the several theories advanced by different authorities on these points, but without being able to reach any perfectly satisfactory conclusion. The author favors a solid rather than a molten nucleus within the earth, and would attribute the volcanic action in general to high temperature joined with abundance of vapors and gases beneath the volcanic vent; but no new theory is offered to account for the occurrence of these conditions within the crust of the earth.

The book is illustrated with numerous diagrams and wood cuts and will well repay the general reader, as well as those who are more especially interested in Vulcanology. It is a fair presentation, so far as its limits allow, of the present state of knowledge and opinion in that department of science. C. G. R.

Princeton, Nov. 26, 1881.

16. *Mineralogical Notes;* by EDO CLAASSEN.—(1.) *Analysis of orthoclase* from Ishpeming, Marquette County, Michigan. (Communicated.)—The orthoclase occurs in crystals on hematite, the so-called No. 10 ore of the Cleveland Iron Mining Company. The crystals are small and sometimes single, but mostly in twins. They are often united in bundles. The single crystals form four-sided prisms with oblique terminations. The measurement of the angles, which could not be done very exactly on account of the curved planes, by the common goniometer, showed that these planes were I and $2\text{-}i = (\infty P, 2P\infty)$. Hardness of the crystals about 6; color, white, reddish and red. They dissolved in no acid except hydrofluoric acid, but were easily decomposed by fusion with the carbonates of sodium and potassium. Although the greatest care was taken to get the crystals for the analysis in a pure state, a magnifying lens still shows a few very small particles of the ore remaining with them, so that in the analysis below the amount of Fe_2O_3 should be somewhat diminished. It is evident that an analysis of the perfectly white crystals would not afford any iron. The reddish and red crystals contain—

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	H_2O
63·712	17·546	1·644	0·714	0·172	13·807	0·233	0·612	0·606=99·046

The P_2O_5 in another sample amounted to 0·685 per cent.

(2.) *On regular polyhedral cavities in hematite.* Some time ago I observed several specimens of micaceous hematite, from the Lake Superior iron region, containing cavities from one-eighth to three-quarters of an inch in diameter. An exact examination showed them to be bounded by five-sided planes similar to those of the pentagonal dodecahedron of pyrite. By the measurement of their angles it was put beyond doubt that these cavities once contained crystals of pyrite. Access of air and water had evidently effected their disappearance. Not the smallest particle of this mineral, however, could be met with either in these cavities or in any other part of the ore.

Cleveland, Ohio, November, 1881.

17. *Analysis of the Emerald-green Spodumene from North Carolina;* by F. A. GENTH.—The following analysis of the Alexander County spodumene (*hiddenite*) was furnished by Dr. Genth, and should have been added to the article on the crystalline form of the species on page 179 of the last volume, but was not received in time. The presence of a small quantity of chromium shown by this analysis is interesting as bearing upon the question as to the cause of the color to which this variety of spodumene owes its beauty:

SiO_2	Al_2O_3	Cr_2O_3	FeO	Li_2O	Na_2O	K_2O
63·95	26·58	0·18	1·11	6·82	1·54	0·07=100·25

Specific gravity = 3·177.

18. *New Mineralogical Works—Lehrbuch der Mineralogie von* Dr. GUSTAV TSCHERMAK. Erste Lieferung. 192 pp. 8vo. Vienna, 1881 (Alfred Hölder).—The new work of Professor Tschermak promises to be a most important addition to the small number of mineralogical text-books of the higher grade which represent the present state of the science in all its departments. The first part, now published, which will form about one-third of the completed volume, contains the Crystallography and the larger portion of the Physical Mineralogy. The author presents the subject from the advanced point to which the science has reached through the rapid progress made during the past few years. The book is throughout an original one, to a limited extent necessarily in the topics discussed, but fully so as regards the way in which old principles are presented. The style is clear and concise, and the author's long experience as a teacher has given him an unusual power in explaining difficult subjects in an intelligible and attractive form.

Materialien zur Mineralogie Russlands von N. von Kokscharof. Volume viii, pp. 33–320. St. Petersburg, 1881.—The first portion of volume eight of the valuable work by Professor Kokscharof on Russian Mineralogy was issued about three years since (this Journal, xvii, 486, 1879). The continuation, now received, contains more or less extended notices of the following species: perofskite, epidote, æschynite, phosgenite, bournonite, greenockite, quartz, samarskite, amphibole, beryl, magnetite, pyroxene, vanadinite, jarosite, sulphur, garnet. Descriptions of the crystals of various artificial compounds are also given. The memoirs contained in the volumes of this series will always be regarded as models of careful and accurate crystallographic work.

Elemente der Mineralogie von Carl Friedrich Naumann, elfte vollständige neu bearbeitete und ergänzte Auflage von Ferdinand Zirkel, 735 pp. 8vo. Leipzig, 1881 (Wm. Engelmann).—The appearance of a new edition of the long known and always valued Mineralogy of Naumann is an event deserving of notice. This edition, the eleventh, has been prepared, as was the preceding (this Journal, xiv, 424, 1877), by Professor Zirkel, of Leipzig. The new matter added gives the more important results of mineralogical investigations during the past four years. It speaks

well for the position which this work holds, that it is possible for the publishers to reprint the entire volume after so comparatively short an interval.

Mineral Karakteristik: En handledning vid bestämmandet af Mineralier och Bergarter af Dr. F. J. Wiik. 217 pp. small 8vo. Helsingfors, 1881.—This little volume will doubtless receive the welcome it deserves among the special class of students and readers for whom it is intended. It ranks with the well known works on Determinative Mineralogy: for example, those of Weisbach and Websky on the physical side, and of von Kobell and Brush on the chemical side. Professor Wiik devotes the first part of the volume to a general discussion of the crystallographical, physical and chemical character of minerals; the remainder contains brief descriptions of the more important mineral species arranged in three independent systems: first, according to the crystalline form; second, according to the physical characters, luster, color, hardness and specific gravity; third, according to the chemical characters as given chiefly by the blowpipe. The idea of drawing out independently each of these three methods of determining minerals, and of giving under each those characters of the mineral which belong there, is for purposes of instruction an excellent one.

III. Botany and Zoology.

1. *A Manual of the Coniferæ, containing a general Review of the Order, a Synopsis of the hardy kinds cultivated in Great Britain, their place and use in Horticulture, etc., etc.* James Veitch & Sons, Royal Exotic Nursery, King's Road, Chelsea. 1881. pp. 343, roy. 8vo.—We have had the pleasure to receive this large and beautiful volume, the most popular book of the day upon Coniferous trees, as it is the most recent. It is well adapted to its purpose, which is not to serve as a scientific treatise, but to supply the demand for practical information which is constantly made upon an establishment like that of the Messrs. Veitch, and, indeed, is made by the legions of planters of Conifers in Great Britain and elsewhere. It is copiously illustrated by wood engravings, the smaller ones in the letter-press, the larger as separate plates. Among the most notable of the latter, that of a branch and cone (nine inches long) of *Abies nobilis*, grown at Bicton, takes the lead; a view of the famous *Araucaria*-avenue at Bicton faces the title-page; the unrivalled *Araucaria* at Dropmore (now sixty-one feet high and in the most perfect condition) is represented from a photograph specially taken for the purpose; and hardly less interesting are such as the *Taxodium* on the bank of the Thames at Syon House—the lower part only represented, surrounded for sixty feet on all sides with a thick growth of 'knees,' emulating a "cypress swamp" in Carolina; also Earl Ducie's fine *Abies bracteata* at Tortworth, a fir which, wherever it can be healthfully grown "will always be regarded with genuine admiration."

A. G.

2. *Repertorium Annuum Literaturæ Botanicæ Periodicæ, curavit* G. C. W. Bohnenzieg, Custos Bibliothecæ Societatis Teylerianæ. Tom. vi. Haarlem. pp. 420, 8vo.—This most laborious and painstaking work has gone on to the sixth volume, systematically cataloguing the botanical articles in current periodicals. This volume, issued in the year 1881, deals with the articles which were published in the year 1877, in 237 different periodicals.

A. G.

3. *Jahrbuch des Königlichen Botanischen Gartens und des Botanischen Museums zu Berlin;* herausgegeben von Dr. A. W. Eichler. Band I. Berlin, 1881, 8vo, 351, tab. vi.—A new botanical periodical, in the form of an annual volume, intended especially to represent the work done by the accomplished director and others at the Berlin Botanic Garden and Museum. Naturally it will be more devoted to systematic and phænogamous botany than is common in the German journals of the present day; and, as is fitting, the Linnæa will be merged in it.

The form is royal octavo, paper and print excellent, and the type Roman. A proper commencement is the opening article which fills almost half the volume, in which, after a brief statement by Professor Eichler of the condition and operations of the Berlin Botanic Garden and Museum, including the Herbarium, during the three years of his direction, the complete history of these establishments is given by Dr. Urban, the assistant director of the garden. Three plates exhibit ground plans of the garden, in 1801, in 1812, and 1881, and a photographic front view of the museum building, which has just been erected at a cost of about $175,000. The annual cost of maintaining the garden, including the museum, is about $17,500. The present Prussian government is more liberal to it than was the first king Frederic William, who upon its establishment as a real botanical garden, ordered that, in view of the great regard he had for the learning and merits of the Royal Berlin Society of Sciences, that learned society should maintain the garden out of its own scanty funds.

Dr. Eichler has articles upon Inflorescence-bulblets; upon Heterogeneous shoots; upon the nature of the Vine-stem as to its morphology; upon Cephalotus-pitchers; Garcke, a synopsis of *Pavonia* (in which *P. Lecontei* is kept distinct from *P. hastata*, though it seems to be only a waif of that South American species); G. Ruhmer, an article upon wild and cultivated Thuringian hybrids; Urban, on the pollenization of *Lobeliaceæ*, with a monograph of *Monopsis;* F. C. Dietrich, a biography of the collector Sieber, with an enumeration of his distributed collections, and a list of names to the numbers (645) of his Herbarium Floræ Novæ Hollandiæ; Potonié describes the Anatomy of the Lenticels of *Marattiaceæ*, the stomatic apparatus of Ferns, etc.; Ascherson has an article on the subfloral axis as apparatus for dissemination, as in *Stipa*, *Erodium*, *Podopterus*, *Brunnichia*, etc.; and in a note he characterizes a new African *Brunnichia*, the same probably as one which has been or is about to be figured in the Icones Planta-

rum at Kew. Finally, Kuhn gives a synopsis of the species of *Adiantum*, 113 species. A. G.

4. Engler's *Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie* is well kept up. In November the fourth fasciculus of the second volume was published (Leipzig, Engelmann), continuing the systematic digest of botanical publications—whether works or articles—in the year 1881, and also containing four original articles. A. G.

5. Hooker's *Icones Plantarum*, part III of the fourth volume of the third series, or the fourteenth volume of the entire work,—issued in October, 1881—is most interesting for its figures of Grasses, in which some of the work in the Genera Plantarum is anticipated. There is a plate in which some of our botanists may recognize the *Lepturus paniculatus* of Nuttall. Mr. Bentham has ascertained that it is not of this genus, nor much related to it. And he has also found a published name for it, *Schænonardus Texanus*, of Steudel, who, however, had no idea that he had to do with Nuttall's plant. The information we here give will not be gathered from the work before us; for the letter-press for this plate 1360 has inadvertently been omitted. *Munroa squarrosa*, Torr., and *Dissanthelium Californicum* are other North American Grasses, the latter being the rare *Stenochloa Californica* of Nuttall, which proves to belong to a South American genus founded by Presl. A. G.

6. *Occurrence of an additional specimen of Architeuthis at Newfoundland;* by A. E. Verrill.—This specimen (No. 27) was taken at Portugal Cove, near St. John's, Newfoundland, November 10, 1881. This example was nearly perfect and was shipped to New York, packed in ice, on the steamer "Catima," Capt. Davies. In an article in the New York Herald, of November 25th, the following measurements of the fresh specimen were given, on the authority of Inspector Murphy, chief of the Board of Public Works Department: Length of body, 5·5 feet; length of the head, 1·25 feet; total length, to end of tentacular arms, 28 feet; circumference of body, 4·5 feet. A photograph of this example was made by Mr. E. Lyons, of St. John's, and a cut copied from this has been published in Harper's Weekly, for December 10, 1881.

This specimen was purchased by Mr. E. M. Worth and preserved in alcohol at his museum, 101 Bowery street, New York, where, through the courtesy of Mr. Worth, I have recently had an excellent opportunity for a satisfactory examination. Although a valuable specimen, it is not in all respects perfect, for the tips of all the sessile arms are broken off, and many of the suckers are gone; one-half of the caudal fin had apparently been lost and the wound healed some time before the creature's death; the eye-balls had been burst in handling, and the pen mostly destroyed. But notwithstanding these defects, this specimen is more nearly perfect than any that has been previously brought to this country, and has, therefore, afforded me important information in respect

to several of the organs that have not been preserved in any other specimen. Of these points the following may be mentioned: The siphon is large, with the aperture slightly bilabiate, and four inches broad; valve large; dorsal bridles well-developed; siphon-pit broad, not very deep, *smooth;* eye-lids large, only slightly angulated and thickened, with a shallow sinus; diameter of opening, 4·5 inches; transverse nuchal crest, back of eyes, evident, but not much elevated; one longitudinal crest, on each side, short and not much raised, the others apparently rudimentary, possibly rubbed off. The median dorsal angle of the mantle-edge is rather prominent; lateral angles evident; lateral connective cartilages of the mantle very simple, consisting only of a short, simple, longitudinal ridge; connective cartilages on the base of the siphon simple, long-ovate, somewhat oblique, slightly concave. Anterior tip of the pen very thin, broad, obtuse. The caudal fin was too much mutilated before and after death to afford additional information. When examined by me, after it had been in alcohol about two weeks, the body measured 4·16 feet in length, along the side; length of head, 1·25 feet; circumference of body, 4 feet; of sessile arms, 7·5 to 8·5 inches; length of ventral arms, minus tips, 4·66 feet; of tentacular arms, 15·5 feet.

7. *Descriptions of some new and rare Cephalopoda. Part II.*< *Trans. Zool. Soc. London, xi, part* 5, *pp.* 131–170, *pl.* 23–35, *June*, 1881. By Richard Owen.—This important paper is of special interest on account of the figures and descriptions that it contains of two gigantic species.

Under the new name, *Enoploteuthis Cookii*,* Professor Owen has described in detail, and has given excellent figures of most of the existing parts of this large and remarkable cephalopod, which have been so long preserved in the Museum of the College of Surgeons, and have often been referred to, but hitherto have never been scientifically described, (see Ceph. N. E. Am., p. 241).† It is to be regretted, however, that Professor Owen has neither described nor figured the dentition of the radula, in a manner to enable it to be used as a systematic character. His statement in regard to it is of the most general kind, and shows only that there are seven rows of teeth. It is also a matter of

* The synonymy of this species is as follows:

Enoploteuthis Cookii Owen.

Trans. Zool. Soc. London, xi, p. 150, pl. 30, figs. 1–3; pl. 31, figs. 1–4; pl. 32, figs. 1–6, pl. 33, fig. 1, (restoration), June, 1881.

Seppia unguiculata Molina, 1810 (no description).

Enoploteuthis Molinæ D'Orbigny, Ceph. Acétab., p. 339, 1845–1848.

? *Enoploteuthis Hartingii* Verrill, this vol., p. 241, pl. 24, figs. 4–4*b*, 1880.

† In referring in this notice to my own work upon Cephalopods, I have made all the references to my paper in Trans. Conn. Acad., v, on "The Cephalopods of the Northeastern Coast of America." Of this, Part I (80 pp., 14 pl.), relating to the large species, was published December, 1879 to March, 1880. A still more detailed report by me on the same subject is contained in the report of the U. S. Fish Commission for 1879, not yet issued. Many of the statements and descriptions quoted are also contained in several of my former articles in this Journal.

surprise that he has not compared any of the portions that he describes with the corresponding parts of the equally large and very closely allied *Enoploteuthis*, carefully described and figured by Harting in 1861 (see Ceph. N. E. Am., p. 240), and to which I gave, in 1880, the well-merited name, *Hartingii*. It is not improbable that the two forms are really identical, but this cannot be certainly determined from the figures, because the corresponding parts are not always represented in the same position, and it is uncertain whether the corresponding arm is preserved in the two cases. Harting figures, rather poorly, the teeth of the radula, which appear to be very peculiar, if his figure is correct, (see my pl. xxiv, fig. 4*b*). The shape of the mandibles appears to be different in the two species, however, and the large hooks differ in form.

Professor Owen has also given a somewhat detailed description, with figures, of the large cephalopod-arm, long preserved in the British Museum. But this had previously been pretty fully described by Mr. Saville Kent, in 1874, whose description has been quoted by me (see Ceph. N. E. Am., pp. 241–242). Professor Owen, like Mr. Kent, fails to state to which pair of arms the specimen belongs. This is a very important omission, for in *Architeuthis*, as in most other genera, the arms belonging to different pairs differ in form and structure. The describers of this arm would doubtless have been able to ascertain to which pair it belonged by a direct comparison with the arms of *Ommastrephes*, or any other related genus.

For this arm, Professor Owen endeavors to establish a new genus and species (*Plectoteuthis grandis*). The genus is based mainly on the fact that there is a marginal crest along each outer angle, and a narrow, protective membrane along each side of the sucker-bearing face. These peculiarities are precisely those seen in the *ventral arms* of *Architeuthis*, and have already been described by me in former articles (see Ceph. N. E. Amer., p. 214), as found in *A. princeps*. Similar membranes or crests are found on the *dorsal* arms of *Sthenoteuthis pteropus* and other related species. The protective or marginal membranes outside of the suckers are found in many allied genera.

The suckers on the arm, as described and figured by Professor Owen, are exactly like those of *Architeuthis*. Therefore, there is no ground whatever for referring this arm *to any other genus*, and *Plectoteuthis* must become a synonym of *Architeuthis*.

Whether the arm in question belongs to a species distinct from those already named, I am unable to say. There is, apparently, nothing to base *specific* characters upon, except the form of the suckers and of their horny rings. But the description of the horny rings is not sufficiently precise, nor the figures sufficiently detailed, to afford such characters. If the arm is one of the ventral pair, as seems probable, the suckers as figured by Professor Owen, and especially as more fully described by Mr. Kent, agree closely, but not perfectly, with those of the Newfoundland specimens; in the

latter the sucker-rings of the ventral arms are at most only slightly denticulated on the inner side, and most of them are entire on that side. But they also agree well with those of the *Architeuthis Hartingii*, as figured by Harting. Those of the original *A. dux* Steenst., have neither been described nor figured. As this arm cannot, at present, be referred with certainty to any of the named species, it may be best to record it as *Architeuthis grandis*, until better known.

In the same article, Professor Owen has given a good figure (pl. 33, fig. 2), of the tentacular arm of the Newfoundland specimen (my No. 2), copied from the same photograph described by me (see Ceph. N. E. Am., pp. 181, 182, 208, 209). To this he applies the name, *Architeuthis princeps*,* without giving any reason for not adopting my conclusion that it belongs to *A. Harveyi*. But he does not, in any way, refer to the latter species, although he mentions the specimen (my No. 5), or rather the photograph of the specimen, on which that species was based. He apparently (on p. 162), supposes that both photographs and Mr. Harvey's two series of measurements refer to the same specimen, which is by no means the case, as had been sufficiently explained by me, in several former papers.†

The brief account, given by Professor Owen, of the large Cephalopods described by others includes none additional to those noticed in my report. On the other hand he omits those described by Harting; those described by Mr. Kirk, from New Zealand; and several others.

Professor Owen has given a description and colored figure of a cephalopod without locality, under the name of *Ommastrephes ensifer*, for which he proposes the subgeneric name *Xiphoteuthis*. The latter name is, however, preoccupied by Huxley. His species is a typical example of my genus *Sthenoteuthis* (1880) and appears to be identical in every respect with *S. pteropus* (see Ceph. N. E. Amer., pp. 228–233, pl. 55, figs. 2, 2*a* and pl. 36, figs. 5–9), from Bermuda. But Professor Owen fails to mention one of the most characteristic features of this group of squids, viz., the connective tubercles and smooth suckers on the proximal part of the tentacular club, nor is his figure sufficiently detailed to indicate this char-

* By a singular mistake, Professor Owen, on p. 163, states that this species was named *A. princeps* by Dr. Packard, in February, 1873. But according to his own statement on p. 161, the specimen was not actually obtained till December, 1873, *at least nine months after Dr. Packard's article was printed.* In truth, the name *princeps* was first given by me in 1875, to designate a pair of very large jaws. Neither this nor any other name appears on the cited page of Dr. Packard's article, though he elsewhere referred the same jaws doubtfully to *A. monachus*.

† It seems incredible that Professor Owen could have made these mistakes, had he actually examined either of my former papers, in which these specimens (with several others), have been described in detail with many figures, not only from the photographs, but from the preserved specimens also. He does, however, refer to my paper in the Trans. Conn. Acad., vol. v. But as he states (p. 162) that in it "a brief notice is given of Mr. Harvey's squid," it is fair to suppose that the reference is taken at second-hand, for it is not to be supposed that he would have considered sixteen pages of text, accompanied by five plates, a "*brief notice.*"

acter, nor even the actual arrangement and structure of the other suckers of the club. The high median crests and broad marginal webs of the 3d pair of arms are well shown, but these are about equally broad in *S. pteropus* and *S. megaptera*, and are also present in all the related species of this group.

Owen's specimen had a total length of 3 feet; length of body, 15 inches; of head to base of dorsal arms, 3·7; of 3d pair of arms, 12; of tentacular arms, 21; breadth of caudal fin, 12·6; length of their attached bases, 6·6; breadth of body, 5; length of 1st, 2d, 3d, 4th pairs of arms, 8·9, 11, 12, and 9·6 inches respectively. The specimen is a female. It agrees very closely in size with the Bermuda specimen described by me, and its proportions do not differ more than is usual with alcoholic specimens of any species preserved under different circumstances, and in alcohol of different strength. The original specimen of *S. megaptera* V., is considerably larger.

A handsome squid from the China Sea, is described as *Loligopsis ocellata*, sp. nov. (p. 139, pl. 26, figs. 3–8, pl. 27). This is evidently not a true *Loligopsis*, but belongs, in all probability, to my genus *Calliteuthis* (1880). It agrees very closely, even to the coloration, and the form of the fins and pen, with my *C. reversa*, but differs in having serrate suckers. This species should, therefore, be called *Calliteuthis ocellata*. The genus probably belongs to the Chiroteuthidæ. It is much larger than my specimen, but, like the latter, it had lost the tentacular arms.

The remaining species described are as follows: *Tritaxeopus cornutus*, gen. et sp. nov., a large Australian octopod, with three rows of suckers; *Sepia palmata*, nov., Australia; *Sepioteuthis brevis*, nov., Japan; *Sepiola Owceniana* D'Orb., anatomy; *Onychoteuthis raptor*, nov. A. E. VERRILL.

8. *The Zoology of H. M. S. Challenger, Part IX. Report on the Echinoidea;* by ALEXANDER AGASSIZ. 4to. 321 pp., 65 plates. 1881.—In this elaborate and very valuable report the author not only describes in detail and handsomely and profusely illustrates the numerous new forms collected by the Challenger, but also gives a very valuable review of the known facts in respect to the geographical and bathymetrical distribution of all the known living echini, and their relations to those of the Jurassic, Cretaceous* and Tertiary ages. The first nineteen pages are devoted to classification and to special features in the structure of echini,—especially the plates, spines, and pedicellariæ. Several plates are also devoted to these structural features. Among the large number of new and strange forms dredged in the deep seas, the two families most conspicuous on account of their unusual characters and forms, and their numbers, both in species and individuals, are the *Echinothuridæ* and the *Pourtalesiæ*. Of the former group, three genera and twelve species are here described. Some of these are of large size, and all have flexible shells, with more

*The chapter on the relation of the existing and the Cretaceous forms has been reprinted in this number (see p. 40).

or less imbricated plates. In the general account of this group its possible relationship with the Palæozoic echini is discussed, in a very suggestive way. Of the curious *Pourtalesiæ*, seven genera and thirteen species (12 new) are described, all of them from deep water, and nearly all from the southern hemisphere.

The total number of species enumerated from this collection is 139, of which 52 species and 15 genera were new. The total number of existing species included in the geographical lists is 297, belonging to 107 genera. This is an increase of 90 species and 25 genera over those included in the author's Revision of Echini (1872–4). Of the whole number, 201 known species are regarded as "littoral," occurring in less than 100 fathoms, though some of these (36 species) range to much greater depths; 46 are regarded as "continental," ranging mainly from 100 to 450 fathoms in depth, though 10 of these also go down to much greater depths; of true "abyssal or oceanic" species, 50 are enumerated, most of them ranging below 350 fathoms, often to 1000 fathoms, 12 descending even to more than 2000 fathoms; but these oceanic species are also associated with 10 littoral and 14 continental species, some of which also extend to great depths. The greatest depth from which Echini were dredged by the Challenger was 2900 fathoms. A. E. V.

9. *On the Geographical Distribution of certain fresh-water Mollusks of North America, and the probable causes of their variations;* by A. G. Wetherby, A.M. Journal Cincinnati Soc. Nat. Hist., Jan. 1881.—Professor Wetherby here gives the facts, gathered from a wide range of observation, respecting the distribution of certain groups of fresh-water Mollusks in American waters—the *Unionidæ* and *Strepomatidæ*, with reference to conclusions as to the origin of the species to be presented in another paper. The principal points brought out are as follows:

No species of the *Strepomatidæ* and but few of the *Unionidæ* occur in New England; and the latter, so occurring, are species of many varietal forms found elsewhere on the Atlantic slope; a few of them only having a wide westward and southward range. One New England species, *Margaritana margaratifera* Lamk., also European, is wanting across the whole interior of the continent, but exists in the drainage of the Pacific slope.

The *Strepomatidæ* occur west of the Green Mountains, and are divisible into two geographical groups, a western and a southern.

The *Unionidæ* of the Ohio drainage area, include about a tenth of all described North American species, being 82 in number, of which 70 are species of *Unio*, 17 of *Margaritana*, and 5 of *Anodonta;* these Ohio types extend north of this stream to the limits of the Mississippi drainage, and south and southwestward to Western Texas; while the *Strepomatidæ* are few over this area.

New species of *Unionidæ* and new genera and species of *Strepomatidæ* appear on crossing the Ohio and going south. The new forms begin to appear in Kentucky and continue

through Tennessee to the southern and eastern limits of the Ohio drainage. The facies of the groups of species which this part of the Ohio drainage contains stamps them as of a different fauna from those north.

The Alabama drainage area is anomalous, it affording 184 species, according to describers—but half of which, however, are anything more than varieties. Two genera, of 30 described species, are not found elsewhere — *Schizostoma* and *Tulostoma*; and these kinds, with the peculiar species of *Goniobasis*, belong to a different fauna from many of the Unionidæ associated with them. The region contains the *Unio spinosus*, in the Altamaha River.

The only other spinous Unio, *U. collinus*, occurs in New River, Virginia, on the western slope of the Appalachians, far to the north.

Some of the species never present any varieties that could be taken for distinct species. This is true, among the Ohio types, of *U. tuberculatus*, *U. cylindricus*, *U. irroratus*, *U. anodontoides*, *U. cornutus*, *U. rectus*, *U. triangularis*, *Margitana dehiscens*, and others. Many other species are exceedingly variant and have led to the naming of many so-called species that are only varieties.

The facts in the second part of this important paper will be published in the following number of this Journal.

IV. Astronomy.

1. *Elements of Comet VII*, 1881 (*Swift*).—Professor Boss of the Dudley Observatory has computed the following elements of Comet VII, 1881 (Swift), from observations made by him on November 20, 28 and December 10.

$T = 1881$, November 17·41 Washington Time.
$\omega = 116^\circ\ 30'$
$\Omega = 180\ \ 59$
$i = 144\ \ 58$
$\log q = 0{\cdot}2841$

This comet is remarkable for its great perihelion distance. The following Ephemeris may be of service, in case the comet does not prove too faint for observation.

Ephemeris for Washington, midnight.

1882.	α	δ	$\log \Delta$.	Brightness.
Jan. 7	$23^h\ 37^m\ 36^s$	$+20^\circ\ 07'$	0·3050	·31
11	38 43	+18 19	0·3265	·28
15	40 15	+16 44	0·3469	·25
23	43 52	+14 07	0·3843	·20
31	48 00	+12 04	0·4171	·17

Brightness November 20 taken as unity. x.

2. *The Longitude of Morrison Observatory, Glasgow, Mo.*; by Professor J. R. Eastman, U. S. N., and Professor H. S. Pritchett, Astronomer at Morrison Observatory, now of Washington Uni-

versity, St. Louis. 15 pp. 4to. Washington, 1881. (Washington Observations for 1877. Appendix V.)—By means of a series of electric signals, exchanged between the Observatory at Washington and the Morrison Observatory, at Glasgow, Mo., it has been determined that the transit circle of the latter observatory is $1^h\ 3^m\ 5^s{\cdot}926$ west of the central dome of the United States Naval Observatory.

V. Miscellaneous Scientific Intelligence.

1. *Annual Report of the Chief Signal Officer of the Army to the Secretary of War for the year* 1881. 86 pp. 8vo. Washington, 1881.—The Report of General Hazen is very satisfactory as showing that under his control the United States Signal Service is not only to be kept up to the high standard which was maintained under the late General Myers, but is to be made more efficient both in its practical bearings and still more from a scientific point of view. The report details the numerous respects in which progress has been made, and in which it is promised in the future. These include various details of the service, such as the establishment of a permanent school of instruction at Fort Myers, Va.; the raising of the standard of the *personnel* of the Signal Corps; the systematization of the duties of the Service; the preparation of new instructions for observers, and many improvements in the publication of information for the benefit of the public in the various ways in which changes in the weather may affect their interests in the different parts of the country, as in "river warnings," "frost warnings" for the cotton States, special bulletins in regard to tornadoes, "cold and hot waves," and so on.

From a scientific point of view, the most important advances which are being made in the Signal Service, and those which promise most for the future, are in connection with what is called the "Scientific and Study Division," and which has for its object the research and investigation into the laws of meteorology. This division has been placed in charge of Professor Abbe, and under him three gentlemen have been appointed upon examination —viz: Messrs. Winslow Upton, H. A. Hazen and Frank Waldo—who are to act as expert mathematicians and "computers."

In connection with this division a number of "Consulting Specialists" have been selected to whom strictly scientific questions will be submitted—as those concerning the standard barometer and thermometer, pendulum apparatus and observations, atmospheric absorption of solar heat, ground electrical currents and atmospheric electricity, chemical analysis of air, collection and examination of atmospheric dust. In addition, a Committee of Conference was appointed by the National Academy at the Washington meeting, April 17, consisting of nine prominent scientific men to whom "the Chief Signal Officer may refer, as occasion arises, questions of meteorological science and its applications." Of special scientific investigations undertaken in connection with

the Signal Service and promising important results may be mentioned the expedition of Professor Langley to Mount Whitney during the past season, to study the absorption of the sun's heat by the atmosphere. The Signal Service has also taken up the important subject of standard time, to which reference has been made in this Journal (vol. xxi, p. 414). Finally, General Hazen mentions what has been done by the Service in coöperation with the International Committee of Polar Research, which has, during the past two years, organized a system of stations in both Arctic and Antarctic regions. At these stations observations will be conducted hourly and bi-hourly, in meteorology, magnetism and tides, with special observations on gravity, auroras, earth currents, etc. The knowledge thus gained will be invaluable in affording data for the solution of many obscure meteorological problems. The stations established by the United States are at Lady Franklin Bay, 81° 40′ N. lat., 64° 30′ W. long., and at Point Barrow, Alaska, 71° 27′ N. lat., and 156° 15′ W. long.

2. *National Academy of Science, Nov.*, 1881.—The following are the titles of papers entered.

On a Gigantic Salpa found in the Gulf Stream, A. Agassiz.

The Echini of the Challenger Expedition, A. Agassiz.

The Distribution of Corals of the Tortugas, A. Agassiz.

The Porpitidæ, the Velellidæ, and the Surface Fauna of the Gulf Stream, A. Agassiz.

Classification of the Dinosauria, O. C. Marsh.

Succession in Time of the Allotheria, O. C. Marsh.

On Complex Inorganic Acids, W. Gibbs.

On the Theory of the Dynamo-electric Machine, W. Gibbs.

Mean annual rain-fall for different countries of the Globe, E. Loomis.

On the Phenacodontidæ, a new group of Perissodactyla, E. D. Cope.

A comparison between the shells of Kjökkenmöddings and present shells of the same species, E. S. Morse.

On the Objects and Results of the Recent Expedition to Mt. Whitney, S. P. Langley.

On a form of regulator for driving-clock of an Equatorial, C. A. Young.

On the Logic of Number, C. S. Peirce.

Statement respecting experiments on the Velocity of Light, S. Newcomb.

Notice of a remarkable mineral vein in the Black Range (Negretta Mts.) of Socorro County, New Mexico, B. Silliman.

Facts regarding Sorghum and some conclusions as to its value as a source of sugar, P. Collier.

On a new form of Volumescope, R. E. Rogers.

On Mascart's electrometer and its use as a Meteorological instrument, G. F. Barker.

On Hydrometer Scales, C. F. Chandler.

On Chinoline; its Synthesis and Medical uses, H. Morton.

On the Fossil and Recent Faunæ of the Oregon desert, E. D. Cope.

Biographical Memoir of the late Professor S. S. Haldeman, J. P. Lesley.

Newly determined line of the Terminal Moraine across Pennsylvania, J. P. Lesley.

An Elementary Treatise on Electricity, by JAMES CLERK MAXWELL, M.A.; edited by WILLIAM GARNETT, M.A. 208 pp. 8vo, with 6 plates. Oxford, 1881. (Clarendon Press.)

Tables of Qualitative Analysis, arranged by H. G. MADAN, M.A., F.C.S. 20 pp. 4to. Oxford, 1881. (Clarendon Press.)

OBITUARY.

Mr. ROBERT MALLET, F.R.S., long known for his valuable memoirs on earthquakes and volcanoes, died on the fifth of November, at the age of seventy-one. Mr. Mallett was born in Dublin on June 3, 1810. He qualified himself early in life as an engineer, and for a number of years was actively engaged in the work of his profession. His taste for scientific study led him also to spend much time in study and research, and in 1846 his first paper on earthquake phenomena was published in the Philosophical Magazine. Two years later he published, in the Transactions of the Royal Irish Academy, a paper containing an exposition of his views on wave-movement in earthquakes, and from that time until the end of his life his scientific activity did not cease, although during his later years he was afflicted with almost total blindness. Altogether he was the author of more than seventy memoirs, besides several separately published works. These memoirs relate for the most part to the phenomena of earthquakes and volcanoes, and will always be of the greatest value to the student of these subjects; in fact the subjects may be said to have been, in many respects, developed by him. Among the more important of his scientific contributions may be mentioned the Earthquake Catalogue completed, with the aid of his son (Professor J. W. Mallet, of Virginia), in 1858; also the memoir containing his observations on the Neapolitan earthquake published in two volumes, in 1862, in which for the first time he laid down the method of studying such phenomena; and still again the paper on Volcanic Energy published in the Transactions of the Royal Society in 1872. The last memoir mentioned contains the results of a series of careful experiments and of calculations based upon them, on the amount of heat produced by the crushing of different kinds of rocks; the conclusions reached, in regard to the probable mechanical source of much of the heat involved in metamorphic action and volcanic phenomena, have exerted a wide influence, and their importance can hardly be overestimated.

(The facts contained in this notice are mostly taken from *Nature* of December 1.)

APPENDIX.

ART. VII.—*Classification of the Dinosauria;* by Professor O. C. MARSH.*

IN the May number of the American Journal of Science, (page 423), I presented an outline of a classification of the Jurassic Dinosaurian Reptiles of this country which I had personally examined. The series then investigated is deposited in the Museum of Yale College, and consists of several hundred individuals, many of them well preserved, and representing numerous genera and species. To ascertain how far the classification proposed would apply to the material gathered from wider fields, I have since examined various Dinosaurian remains from other formations of this country, and likewise, during the past summer, have visited most of the museums of Europe that contain important specimens of this group. Although the investigation is not yet completed, I have thought the results already attained of sufficient interest to present to the Academy at this time.

In previous classifications, which were based upon very limited material compared with what is now available, the Dinosaurs were very generally regarded as an order. Various characters were assigned to the group by von Meyer, who applied to it the term *Pachypoda;* by Owen, who subsequently gave the name *Dinosauria*, now in general use; and also by Huxley, who more recently proposed the name *Ornithoscelida*, and who first appreciated the great importance of the group, and the close relation it bears to Birds. The researches of Leidy and Cope in this country, and Hulke, Seeley, and others in Europe, have likewise added much to our knowledge of the subject.

An examination of any considerable portion of the Dinosaurian remains now known will make it evident to any one familiar with reptiles, recent or extinct, that this group should be

* Read before the National Academy of Sciences, at the Philadelphia meeting, November 14, 1881.

regarded, not as an order, but as a sub-class, and this rank is given it in the present communication. The great number of subordinate divisions in the group, and the remarkable diversity among those already discovered indicate that many new forms will yet be found. Even among those now known, there is a much greater difference in size and in osseous structure than in any other sub-class of vertebrates, with the single exception of the placental Mammals. Compared with the Marsupials, living and extinct, the *Dinosauria* show an equal diversity of structure, and variations in size from by far the largest land animals known—fifty or sixty feet long, down to some of the smallest, a few inches only in length.

According to present evidence, the Dinosaurs were confined entirely to the Mesozoic age. They were abundant in the Triassic, culminated in the Jurassic, and continued in diminishing numbers to the end of the Cretaceous period, when they became extinct. The great variety of forms that flourished in the Triassic render it more than probable that some members of the group existed in the Permian period, and their remains may be brought to light at any time.

The Triassic Dinosaurs, although so very numerous, are known to-day mainly from footprints and fragmentary osseous remains. Not more than half a dozen skeletons, at all complete, have been secured from deposits of this period; hence, many of the remains described cannot at present be referred to their appropriate divisions in the group.

From the Jurassic period, however, during which Dinosaurian reptiles reached their zenith in size and numbers, representatives of no less than four well-marked orders are now so well known that different families and genera can be very accurately determined, and almost the entire osseous structure of typical examples, at least, be made out with certainty. The main difficulty at present with the Jurassic Dinosaurs is in ascertaining the affinities of the diminutive forms which appear to approach Birds so closely. These forms were not rare, but their remains hitherto found are mostly fragmentary, and can with difficulty be distinguished from those of Birds, which occur in the same beds. Future discoveries will, without doubt, throw much light upon this point.

Comparatively little is yet known of Cretaceous Dinosaurs, although many have been described from incomplete specimens. All of these appear to have been of large size, but much inferior in this respect to the gigantic forms of the previous period. The remains best preserved show that, before extinction, some members of the group became quite highly specialized.

Regarding the Dinosaurs as a sub-class of the REPTILIA, the forms best known at present may be classified as follows:

SUB-CLASS DINOSAURIA.

Premaxillary bones separate; upper and lower temporal arches; rami of lower jaw united in front by cartilage only; no teeth on palate. Neural arches of vertebræ united to centra by suture; cervical vertebræ numerous; sacral vertebræ coössified. Cervical ribs united to vertebræ by suture or ankylosis; thoracic ribs double-headed. Pelvic bones separate from each other, and from sacrum; ilium prolonged in front of acetabulum; acetabulum formed in part by pubis; ischia meet distally on median line. Fore and hind limbs present, the latter ambulatory and larger than those in front; head of femur at right angles to condyles; tibia with procnemial crest; fibula complete. First row of tarsals composed of astragalus and calcaneum only, which together form the upper portion of ankle joint.

(1.) Order SAUROPODA (Lizard foot.) Herbivorous.

Feet plantigrade, ungulate; five digits in manus and pes; second row of carpals and tarsals unossified. Pubes projecting in front, and united distally by cartilage; no post-pubis. Precaudal vertebræ hollow. Fore and hind limbs nearly equal; limb bones solid. Sternal bones parial. Premaxillaries with teeth.

(1.) Family *Atlantosauridæ*. Anterior vertebræ opisthocœlian. Ischia directed downward, with extremities meeting on median line.

Genera *Atlantosaurus*, *Apatosaurus*, *Brontosaurus*, *Diplodocus*, *? Camarasaurus* (*Amphicœlias*), *? Dystrophæus*.

(2.) Family *Morosauridæ*. Anterior vertebræ opisthocœlian. Ischia directed backward, with sides meeting on median line.

Genus *Morosaurus*.

European forms of this order: *Bothriospondylus*, *Cetiosaurus*, *Chondrosteosaurus*, *Eucamerotus*, *Ornithopsis*, *Pelorosaurus*.

(2.) Order STEGOSAURIA (Plated lizard). Herbivorous.

Feet plantigrade, ungulate; five digits in manus and pes; second row of carpals unossified. Pubes projecting free in front; post-pubis present. Fore limbs very small; locomotion mainly on hind limbs. Vertebræ and limb bones solid. Osseous dermal armor.

(1.) Family *Stegosauridæ*. Vertebræ biconcave. Neural canal in sacrum expanded into large chamber; ischia directed backward, with sides meeting on median line. Astragalus coössified with tibia; metapodials very short.

Genera *Stegosaurus* (*Hypsirhophus*), *Diracodon*, and in Europe *Omosaurus*, Owen.

(2) Family *Scelidosauridæ*. Astragalus not coössified with tibia; metatarsals elongated; four functional digits in pes. Known forms all European.

Genera, *Scelidosaurus*, *Acanthopholis*, *Cratæomus*, *Hylæosaurus*, *Polacanthus*.

(3.) Order ORNITHOPODA (Bird foot). Herbivorous.

Feet digitigrade, five functional digits in manus and three in pes. Pubes projecting free in front; post-pubis present. Vertebræ solid. Fore limbs small; limb bones hollow. Premaxillaries edentulous in front.

(1.) Family *Camptonotidæ*. Clavicles wanting; post-pubis complete.

Genera *Camptonotus*, *Laosaurus*, *Nanosaurus*, and in Europe *Hypsilophodon*.

(2.) Family *Iguanodontidæ*. Clavicles present; post-pubis incomplete. Premaxillaries edentulous. Known forms all European.

Genera *Iguanodon*, *Vectisaurus*.

(3.) Family *Hadrosauridæ*. Teeth in several rows, forming with use a tesselated grinding surface. Anterior vertebræ opisthocœlian.

Genera *Hadrosaurus*, *? Agathaumas*, *Cionodon*.

(4.) Order THEROPODA (Beast foot). Carnivorous.

Feet digitigrade; digits with prehensile claws. Pubes projecting downward, and coössified distally. Vertebræ more or less cavernous. Fore limbs very small; limb bones hollow. Premaxillaries with teeth.

(1.) Family *Megalosauridæ*. Vertebræ biconcave. Pubes slender, and united distally. Astragalus with ascending process. Five digits in manus and four in pes.

Genera *Megalosaurus* (*Poikilopleuron*), from Europe. *Allosaurus*, *Cœlosaurus*, *Creosaurus*, *Dryptosaurus* (*Lælaps*).

(2.) Family *Zanclodontidæ*. Vertebræ biconcave. Pubes broad elongate plates, with anterior margins united. Astragalus without ascending process; five digits in manus and pes. Known forms European.

Genera *Zanclodon*, *? Teratosaurus*.

(3.) Family *Amphisauridæ*. Vertebræ biconcave. Pubes rod-like; five digits in manus and three in pes.

Genera *Amphisaurus* (*Megadactylus*), *? Bathygnathus*, *? Clepsysaurus*; and in Europe, *Palæosaurus*, *Thecodontosaurus*.

(4.) Family *Labrosauridæ*. Anterior vertebræ strongly opisthocœlian, and cavernous. Metatarsals much elongated. Pubes slender, with anterior margins united.
Genus *Labrosaurus*.

Sub-Order CŒLURIA (Hollow tail.)

(5.) Family *Cœluridæ*. Bones of skeleton pneumatic or hollow. Anterior cervical vertebræ opisthocœlian, remainder bi-concave. Metatarsals very long and slender.
Genus *Cœlurus*.

Sub-Order COMPSOGNATHA.

(6.) Family *Compsognathidæ*. Anterior vertebræ opisthocœlian. Three functional digits in manus and pes. Ischia with long symphysis on median line. Only known specimen European.
Genus *Compsognathus*.

DINOSAURIA?

(5.) Order HALLOPODA (Leaping foot.) Carnivorous?

Feet digitigrade, unguiculate; three digits in pes; metatarsals greatly elongated; calcaneum much produced backward. Fore limbs very small. Vertebræ and limb bones hollow. Vertebræ biconcave.
Family *Hallopodidæ*.
Genus *Hallopus*.

The five orders defined above, which I had previously established for the reception of the American Jurassic Dinosaurs, appear to be all natural groups, well marked in general from each other. The European Dinosaurs from deposits of corresponding age fall readily into the same divisions, and, in some cases, admirably supplement the series indicated by the American forms. The more important remains from other formations in this country and in Europe, so far as their characters have been made out, may likewise be referred with tolerable certainty to the same orders.

The three orders of Herbivorous Dinosaurs, although widely different in their typical forms, show, as might be expected, indications of approximation in some of their aberrant genera. The *Sauropoda*, for example, with *Atlantosaurus* and *Brontosaurus*, of gigantic size, for their most characteristic members, have in *Morosaurus* a branch leading toward the *Stegosauria*. The latter order, likewise, although its type genus is in many

respects the most strongly marked division of the Dinosaurs, has in *Scelidosaurus* a form with some features pointing strongly toward the *Ornithopoda.*

The Carnivorous *Dinosauria* now best known may all be placed at present in a single order, and this is widely separated from those that include the herbivorous forms. The two sub-orders defined include very aberrant forms, which show many points of resemblance to Mesozoic Birds. Among the more fragmentary remains belonging in this order, but not included in the present classification, this resemblance appears to be carried much farther.

The order *Hallopoda*, which I have here referred to the *Dinosauria*, with doubt, differs from all the known members of that group in having the hind feet especially adapted for leaping, the metatarsals being half as long as the tibia, and the calcaneum produced far backward. This difference in the tarsus, however, is not greater than may be found in a single order of Mammals, and is no more than might be expected in a sub-class of Reptiles.

Among the families included in the present classification, I have retained three named by Huxley (*Scelidosauridæ*, *Iguanodontidæ*, and *Megalosauridæ*),* although their limits as here defined are somewhat different from those first given. The sub-order *Compsognatha*, also, was established by that author in the same memoir, which contains all the more important facts then known in regard to the *Dinosauria.* With the exception of the *Hadrosauridæ*, named by Cope, the other families above described were established by the writer.

The *Amphisauridæ* and the *Zanclodontidæ*, the most generalized families of the *Dinosauria*, are only known from the Trias. The genus *Dystrophæus*, referred provisionally to the *Sauropoda*, is likewise from deposits of that age. The typical genera, however, of all the orders and suborders are Jurassic forms, and on these especially the present classification is based. The *Hadrosauridæ* are the only family confined to the Cretaceous. Above this formation, there appears to be at present no satisfactory evidence of the existence of any *Dinosauria.*

* Quarterly Journal Geological Society of London. Vol. xxvi, p. 34. 1870.